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Formant Band Widths and Vowel Preference

ARTHUR S. HOUSE

The speech literature dealing with the band width of vowel formants is characterized by disparate sets of data. Current interest in this topic, motivated strongly by the problem of electronic synthesis of high quality speech, led to an investigation of the transient response of the vocal tract (*5*).[1] In that study, the vocal cavities of human subjects were excited by an impulsive acoustic source and the decay rates for the various resonances of the outputs were measured. From these measurements the band widths of the resonances (or formants) associated with various vowel articulations were deduced, and the findings were compared to the experimental literature and to calculated estimates of formant band width. The data were interpreted as supporting that portion of the literature reporting 'narrow' band widths (cf. *5*, Table 3), and various discrepancies in the literature were assigned tentatively to particular instrumental effects. The response-oriented experiment to be reported below was conceived as an alternative (indirect) method of determining typical values of formant band width.

Arthur S. House (Ph.D., University of Illinois, 1951) is a staff member of the Research Laboratory of Electronics, Massachusetts Institute of Technology. An abbreviated report of this study was presented at the 1959 Convention of ASHA in Cleveland, Ohio. This work was supported in part by the U. S. Army (Signal Corps), the U. S. Air Force (Office of Scientific Research, Air Research and Development Command), and the U. S. Navy (Office of Naval Research); and in part by the Air Force Cambridge Research Center under Contract No. AF 19(604)-2061.

[1]The major sources of data on formant band widths are cited in this reference.

Experimental Procedures

Stimulus Generation. The stimuli used in this experiment were generated by a resonance-type electrical vowel synthesizer (*11*). In this synthesizer, two of its five cascaded tuned circuits are fixed and represent the fourth (F4) and fifth (F5) vowel formants; the circuits representing the lowest three formants are variable—changes in capacitive elements result in changes in the center frequency of a given formant, and changes in resistive elements result in changes in the band width of a given formant. A network was included to provide a correction for the resonances of the vocal-tract transfer function higher than F5 (*1*) and for the radiation characteristic of the vocal-tract output.

The duration of each stimulus was approximately 500 msec, including initial build-up and final decay portions of about 100 msec each. The excitation was a quasi-periodic 'sawtooth' wave form analogous to the glottal source. The fundamental frequency of this

TABLE 1. Formant center frequencies (F1, F2, F3) in cps and relative amplitudes (L1, L2, L3) in db for five synthetic vowels. Stimuli were measured with formant band widths of 40, 50, and 60 cps for F1, F2, and F3, respectively; and F4 at 3500 cps, F5 at 4000 cps. Data for comparison (in parentheses) are from Peterson and Barney (*9*; Table 2). Relative amplitudes in both sets of vowels are re F1 of [ɔ]. Increasing the formant band widths of the synthetic vowels resulted in a systematic drop in the level of all formants, but no appreciable changes in relative formant amplitudes. During recording, compensation was made for the reduction in over-all levels resulting from the changes in formant amplitude.

Vowels	*F1*	*L1*	*F2*	*L2*	*F3*	*L3*
[i]	275	−5	2295	−28	3030	−25
	(270)	(−4)	(2290)	(−24)	(3010)	(−28)
[ɛ]	525	−4	1860	−16	2480	−21
	(530)	(−2)	(1840)	(−17)	(2480)	(−24)
[æ]	665	−3	1720	−9	2400	−18
	(660)	(−1)	(1720)	(−12)	(2410)	(−22)
[ɔ]	565	0	825	−5	2425	−39
	(570)	(0)	(840)	(−7)	(2410)	(−34)
[u]	305	−4	875	−20	2245	−47
	(300)	(−3)	(870)	(−19)	(2240)	(−43)

source was 120 cps initially and was inflected upwards about two musical tones (30 cps, or to 150 cps) in a quasi-linear fashion during the temporal course of each stimulus.

Except for formant band widths, the stimuli were given the characteristics of the vowels [i], [ɛ], [æ], [ɔ], and [u] as described by Peterson and Barney (*9*). The formant center frequencies and relative amplitudes for the various vowel stimuli are shown in Table 1.

TABLE 2. Half-power band-width values in cps for the first (B1), second (B2), and third (B3) resonances of synthetic vowels used in the listening experiment.

Band-Width Conditions	*B1*	*B2*	*B3*
A	40	50	60
B	70	85	100
C	100	120	140
D	130	150	180
E	160	190	220
F	190	225	260
G	220	260	300

The half-power band-width values of the lower three formants were varied systematically. The complete set of band-width conditions used in the study is shown in Table 2. As the tabulated values indicate, the half-power band width of the first formant of a given vowel varied from 40 cps to 220 cps in steps of 30 cps, providing seven conditions. In each experimental condition the second and third formants were correspondingly wider, as indicated. The tabulated values of band width were set while the lowest three resonances of the synthesizer were equally spaced in frequency, that is, with center frequencies of 500, 1500, and 2500 cps, to minimize formant interaction during measurement. The values were set precisely by using an electronic counter and rarely deviated by more than two cycles per second. When the resonant frequencies were displaced to

form particular vowel sounds, changes in the effective band-width values of individual resonances were negligible.

Test Construction. Each of the five vowels was synthesized in seven different versions (A, B, . . . , G) corresponding to the conditions shown in the rows of Table 2. For the listening task, the vowels were presented in pairs. In each pair, the band widths of the formants were the only variables; the center frequencies of the formants, temporal and excitation factors were identical. The various pairs were stored electrically on magnetic tape for presentation to listeners; high-quality recordings were made at 15 ips. In the recordings, the intrapair interval was 250 msec, the judgment interval between pairs was about 5 sec, and the over-all amplitude of each stimulus, as indicated by a VU meter, was held constant to ± 0.5 db. Accurate spacing of the stimuli was accomplished automatically by use of a sequential controller with an adjustable time base (*10*).

Data Collection. Listening was done in a sound-treated room and the stimuli were transduced by a loudspeaker. Eight normal-hearing adults served as listeners, and instructions to the listeners were kept to a minimum. In essence they were asked to '. . . decide whether the second sound in each pair is a better or worse representation of the vowel than the first sound.' The listeners' tally sheets indicated which particular vowel was being presented in every instance, so that no absolute identification was required. A short practice series was provided before each session, and each listener attended three sessions. Only one subject was experienced in listening to synthetic speech.

Results

The responses to the listening test were examined in terms of Case V of Thurstone's law of comparative judgment (*3*, chap. 7). Before the scaling was accomplished, however, the major assumptions involved in Case V—normal distribution of the discriminal processes, unidimensionality of the psychological continuum, equality of the various values of the standard deviations of the differences—were investigated by means of Mosteller's (*6*) chi-square test for the discrepancies between obtained and theoretical proportions derived from such comparisons. The compari-

TABLE 3. Preference scales derived from a paired-comparison test of seven conditions of formant band width. Data represent average responses of eight subjects. The conditions in each row are identical with those shown in Table 2; comparisons between columns are not appropriate.

Band-Width Conditions	[i]	[ɛ]	[æ]	[ɔ]	[u]
A	2.72	1.82	1.02	0.56	1.50
B	2.07	1.92	1.48	0.70	1.20
C	1.55	1.58	1.15	0.43	0.88
D	0.89	1.17	0.87	0.37	0.60
E	0.53	0.66	0.33	0.17	0.11
F	0.20	0.30	0.08	0.00	0.00
G	0.00	0.00	0.00	0.03	0.00

sons for each vowel were tested separately and in no case could the assumptions be rejected at the 5% level of confidence. The test, however, is sensitive primarily to lack of unidimensionality; inequalities in the standard deviations of the differences may increase the value of chi square without causing it to reach significance.

Preference Scales. The preferential rankings of the band-width conditions for each vowel are shown in Table 3. The rows are identified with letters (A, B, . . . , G) corresponding to the band-width conditions of Table 2. In each scale, a value of zero was assigned to the least-preferred item to eliminate negative values. The tabulated scale values suggest, primarily, that as the formants of a vowel are widened there is a decrease in the 'naturalness' or acceptability of the vowel; that is, for the vowels of this study the vowel samples having relatively narrow formants were preferred. For the close vowels [i] and [u], for example, condition A (B1 = 40 cps, B2 = 50 cps, B3 = 60 cps) was most preferred; for the remainder of the vowels, condition B (70, 85, 100 cps) was most preferred. These findings are compatible with the data reported by House and Stevens (*5*), and can be interpreted as supporting that portion of the experimental literature that describes formant band widths as relatively narrow (that is, 100 cps or less).

Graphic Analysis. The scales in Table 3 indicate, also, that the listeners failed to prefer the narrowest formants for each of the vowels. Since the scale values for one vowel are not directly comparable to those of another vowel, and since the ranges of the scales for the several vowels differ considerably, it is instructive to examine a graphic representation of the response data.

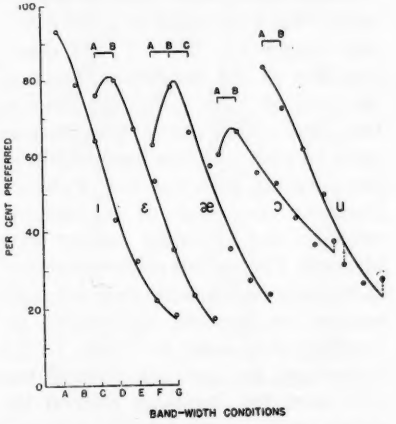

FIGURE 1. Average preferences of eight subjects for the seven band-width conditions of five vowels. Band-width conditions are displayed along the abscissa and correspond to the values shown in the rows of Table 2. To facilitate visual comparison, the response curves are plotted with overlapping abscissae, and abscissa values are shown only for [i]; responses on each curve are arranged in the same order, as suggested by the superior fragments of abscissae. The curves were smoothed by visual inspection.

In Figure 1, the average number of times that a given formant condition was preferred is plotted in per cent for each vowel. The horizontal axis displays the conditions, with the narrowest band widths at the extreme left and progressively wider values to the right. For convenience, the five sets of responses have been displayed together with overlap along the abscissa; the average responses for each vowel are ordered A, B, . . . , G, however. The curves connecting the response averages were smoothed by visual inspection.

The curves of Figure 1 illustrate, once again, the general reduction in the preferences for vowels as their formants are made wider, and also make clearer the nature of the vowel-to-vowel variation of the most-preferred condition. If the smoothing imposed upon the data is reasonable, the curves demonstrate that the subjects' preferences for formant band width varied as a function of tongue height in the classical vowel diagram. The preferences for [i] and [u] are maximal when the formant band widths are the narrowest available—condition A. (Still narrower formants may be even more acceptable.) In a systematic fashion, the maximum average responses to [ɛ] and [ɔ] occur between conditions A and B, while the maximum average response to [æ] occurs between conditions B and C.

Discussion

The correlation of the preferences with phonetic (that is, physiological) descriptions of vowel production argues that these preferences are established in human listeners as a result of the source characteristics of human speech and the lengthy experience of the listeners in processing such speech signals.

Two physical explanations for these correlations are provided by the speech literature. On the one hand, it has been known for some time (*4*, 7, *8*) that during vowel production there is a positive correlation between tongue height and the height of the velum; that is, in American English at least, an open vowel such as [æ] is produced typically with a relatively-lowered velum, providing more coupling to the nasal cavities than occurs during the articulation of a close vowel such as [i]. Such coupling adds to vowel production a source of additional acoustic loss —that is, increases the damping—and manifests itself in spectral changes expressed primarily as increases in formant band width.

On the other hand, Fant (*2*) suggests that during the articulation of open vowels interaction between the vocal-tract configuration and the glottal termination results in losses greater than those found during the production of close vowels. Even in the absence of increased nasal coupling, therefore, the formant band widths of a vowel like [æ] can be expected to be wider than those of [i] or [u].

Figure 1 demonstrates, also, that the average subjective discrimination of band-width changes varied from vowel to vowel; this was suggested, as well, by the varied ranges of scale values in Table 3. The most unsatisfactory response function in the figure is that for [ɔ]. Using this vowel in listening tasks is always hazardous, of course, since its response value is difficult to predict in advance without a good understanding of the phonemic system of each listener. Examination of the responses of the individual listeners to the synthetic [ɔ] samples used in this study revealed that, at one extreme, some subjects were unable to discriminate formant band-width differences at better than a chance level, while, at the other extreme, some subjects responded systematically with no difficulty. Averaging such data, of course, is not to be recommended.

Summary and Conclusions

Five common vowels generated by an electrical synthesizer were used to investigate the subjective importance of the half-power band widths of vowel formants. Seven variants of each vowel were synthesized, paired in all combinations, stored on magnetic tape, and presented to listeners for evaluation. The results suggest the following conclusions:

a. The formants in 'natural' speech are narrow rather than wide (when *narrow* and *wide* are terms descriptive of two sets of band-width measures in the speech literature).

b. On the average, from vowel to vowel there are variations in the most-preferred formant band widths; these variations correlate positively with known characteristics of vowel articulation.

c. Since preferences for formant band width correlate with articulatory events peculiar to given vowels, these preferences can be considered to be based on linguistic experience, that is, the preferences are learned.

Acknowledgment

The assistance of Dr. Ronald Wendahl and members of the Speech Group of the M.I.T. Acoustics Laboratory in the preparation of the stimuli used in the experiment is acknowledged with gratitude.

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Generalization of Stuttering Behavior through Associative Learning

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When attempts have been made to explain stuttering within a learning-model framework, the observed stuttering phenomena have been related to concepts of classical and instrumental conditioning. Adaptation, as evidenced by a decrement in stuttering on successive readings of the same material (*6*, 7, *11*, *13*, *14*, pp. 199-206), has been compared to experimental extinction (*15*). The consistency with which stuttering follows the same set of cues or stimuli (*6*, 7, *11*) is similar to the consistency observed in conditioning behavior and has suggested that stuttering is a learned anxiety reaction (*15*, *16*). Drive-reduction learning theories have been cited to explain stuttering behavior on the assumption that the behavior is reinforced because of the anxiety reduction which accompanies stuttering (*8*, *9*, *13*). An increase in the strength of the stuttering response subsequent to time intervals following adaptation (*4*, pp. 249-255; *5*, pp. 245-248; *15*) has been likened to spontaneous recovery. The possibility that stuttering can be brought under operant conditioning control has been noted (*2*) with reference to the observation that frequency of stuttering increased when escape from noxious stimulus was dependent upon stuttering and decreased when a noxious response was contingent upon stuttering. Penalty and threat of penalty as a result of stuttering, however, were found to increase the amount of stuttering (*3*, *12*) thereby suggesting that stuttering is not to be explained simply within an instrumental-conditioning model.

The question arises as to whether or not an associative-learning model may be used to account for generalization of stuttering behavior. If this model is to be predictive, there must be an explanation of how stuttering becomes attached to words and situations in which previously it was not consistently present. One possibility is that stuttering is a random behavior which has a potential to occur on any

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word or in any situation and that, when it does occur and is reinforced, there is an increased probability that it will occur subsequently on that particular word or in that particular situation. As a description of the learning of stuttering this would be in accord with a conditioning theory model. Another possibility is that stimulus generalization occurs: words and situations which previously did not elicit the stuttering response now serve also as stimulus for the stuttering behavior because of their association with words and situations which do elicit the response. The purpose of the present experiment was to determine whether or not stuttering behavior could be attached to words of low stuttering potential when these words were learned in association with words of high stuttering potential.

Procedure

Paired Associates and Apparatus. The subjects, three female and seven male college-age stutterers, were asked to list those words on which they frequently stuttered and also to rate each of 648 words for expectancy of stuttering, placing them in four categories: *never stutter*, *seldom stutter*, *occasionally stutter*, and *frequently stutter*. The 648 words were the correct responses to Forms C and D of the Multiple-Choice Intelligibility Tests (*1*), words of moderate to high frequency of occurrence in the English language.

Ten words of high stuttering potential were selected for each subject. These words were taken from either the list which the subject had provided as being words on which he frequently stuttered or from words which he had placed in the frequently-stutter category. The latter words were used when the subject was not able to provide a sufficient number of words on which he frequently stuttered. Selected from the never-stutter category for each subject were 30 words, subsequently referred to as words of low stuttering potential. The 40 words, 10 of high potential and 30 of low potential, were arranged in 20 pairs. The first member of each pair was always a word of low stuttering potential. The second member for half of the pairs was a word of high stuttering potential, and for the other half, a word of low stuttering potential. The members of each pair were randomly selected from the categories of words provided by each subject with the restriction that words of obviously high associative value, as chair and table or tree and trunk, were not paired with each other.

Measurement of Stuttering and Associative Learning. Measures were made of (a) frequency of stuttering, using card presentation of the 40 words, and (b) amount of associative learning, using card presentation of one word of each of the 20 word pairs. Learning involved a memory drum presentation of the 20 word pairs. In brief, the experimental sequence was as follows: measurement of stuttering; drum presentation; measurement of stuttering; measurement of learning; drum presentation; measurement of stuttering; measurement of learning. The time for the sequence for each subject was approximately two hours.

Measurement of Stuttering. For the measurement of the frequency of stuttering, each of the 40 words was typed on a 2″ x 4″ card. The subject turned

one card at a time and read the word, continuing until he had read through the 40 words three times. The cards were shuffled after each complete reading of the 40 words. The approximate reading time was one word each three seconds. Two trained observers recorded the presence or absence of stuttering for each word. The two criterion measures for each subject were based on (a) the frequency of stuttering on the 10 words paired with the words of high stuttering potential and (b) the frequency of stuttering on the 10 words paired with the words of low stuttering potential. The criterion measure was obtained by counting the judgments of stuttering made by each of the two observers on each of three readings of 10 words and thus for each of the two criterion measures could vary between zero and 60. Stuttering was measured in this manner three times: before, after 50, and after 100 exposures to the word pairs on the memory drum.

Measurement of Learning. For the measurement of the amount of associative learning, the first word of each pair was typed on a separate card. These words were not seen by the subject but were read to him by the senior experimenter. As each word was read, the subject wrote the second word of that pair. The 20 words were read through three times, in random order for each reading. The approximate reading time was one word each five seconds. The criterion measure was obtained by counting the number of second words of each pair which were correct and thus could vary between zero and 60. Amount of associative learning was measured in this manner following the measurement of stuttering which in turn had followed the 50 and the 100 exposures to the word pairs on the memory drum.

Memory Drum Presentation. For the memory drum presentation, the word pairs had been typed in capital pica letters on a sheet attached to the drum. Both words of each pair were exposed simultaneously. The exposure duration for each pair was 1.5 seconds, total time for each complete presentation of the 20 pairs, 30 seconds. Before the presentation of the words on the drum, the subject was instructed to learn the word pairs as they were exposed so that he would be prepared for a test in which he would be required to write the second word of a pair when he was given the first. As indicated above, there were two memory drum presentations in the experimental sequence, the first of 50 exposures and the second of 100.

Stuttering Potential. Inspection of the data before analysis indicated that in some instances stuttering did not occur on a word which was given as a word of high stuttering potential but did occur frequently on a second member word which was given as a word of low stuttering potential. In these cases, in the analysis of the data, the latter word was regarded as a word of high stuttering potential and the former as a word of low stuttering potential.

Results and Discussion

Differences in frequency of stuttering between the words paired with words of low stuttering potential and those paired with words of high stuttering potential were evaluated for significance by the Sign Test (*10*). The

frequency-of-stuttering measures for the two groups of words were not significantly different for the 50-exposure condition ($p = .19$, one-tailed test) but were significantly different for the 100-exposure condition ($p = .02$, one-tailed test). For the 50-exposure condition, five of the 10 subjects differed in frequency of stuttering on the two groups of words. In four of the five instances there was a greater amount of stuttering on the words paired with words of high stuttering potential than on the words paired with words of low stuttering potential. Nine subjects differed in frequency of stuttering for the two groups of words for the 100-exposure condition. Eight of these differences were in the direction of a greater amount of stuttering on the words paired with the words of high stuttering potential than on the words paired with words of low stuttering potential. A similar evaluation was made for frequency of stuttering on the two groups of words for the before-exposure condition to determine whether the results might have been biased by the words which had been chosen. The result of this evaluation was nonsignificant ($p = .36$, one-tailed test).

Differences in frequency of stuttering between exposure conditions for the words paired with high-stuttering-potential words also were tested for significance. The before-exposure and 50-exposure conditions were not significantly different ($p = .64$, one-tailed test). There were eight subjects who were different for the two conditions, with four of the differences in each direction. The before-exposure and the 100-exposure conditions were not significantly different at the 5% level ($p = .06$, one-tailed test). There were seven nonzero values with six of the differences in the direction of a greater amount of stuttering for the 100-exposure condition than for the before-exposure condition.

The obtained trend was an increase in the mean frequency of stuttering from the before-exposure to the 50-exposure to the 100-exposure condition with mean frequencies of 7.2, 8.5, and 11.1, respectively; the obtained trend for words paired with words of low stuttering potential was in the opposite direction with mean frequencies of 7.7, 6.8, and 6.7, respectively. In other words, the obtained trend for the words paired with those of high stuttering potential was in the opposite direction from the usual adaptation, that is, decrease of frequency of stuttering, expected upon repeated readings of the same material; at the same time, however, the obtained trend for words paired with those of low stuttering potential demonstrates the expected adaptation. These trends, although not statistically significant, might be expected in view of the previously reported finding of a significant difference between frequencies of stuttering on words paired with those of low stuttering and of high stuttering potential. Further evidence is thus provided to support the hypothesis that associative learning affects frequency of stuttering.

Seven of the 10 subjects had achieved close to 100% learning after 50 exposures and eight of the 10 subjects had achieved almost complete learning after 100 exposures. Although the amount of learning was not substantially different between the two exposure times, the additional 50 exposures following the first 50 exposures probably served to

strengthen the associative bonds between the words as seems indicated by the increased amount of stuttering following the 100 exposures as compared to the before-exposure condition.

Inspection was made of the data for evidences of generalization of stuttering behavior which could be accounted for by something other than associative learning. Although there were some instances where stuttering appeared to have spread from the first to the second member of a word pair, a backward conditioning hypothesis was rejected because inspection of the data indicated that there were as many instances where backward conditioning could have occurred and did not occur as there were instances where it did occur. Stuttering generalization to successive word pairs appeared to have occurred in some instances. This appeared in the data for specific individuals rather than for the subjects as a whole.

Summary

The purpose of this study was to evaluate the generalization of stuttering behavior within an associative-learning model. Ten stutterers who served as subjects learned words of low stuttering potential in association with words of high and low stuttering potential. Paired associate learning was by means of a memory drum. Measurement of stuttering was made prior to learning, following 50, and following 100 exposures to word pairs. The results support the prediction of the model that stuttering behavior generalizes through associative learning. Stuttering was significantly more frequent on words learned in association with words of high stuttering potential than on words learned in association with words of low stuttering potential.

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Alternate and Simultaneous Binaural Balancing of Pure Tones

JAMES F. JERGER

EARL R. HARFORD

The classical technique for the direct measurement of loudness recruitment in subjects with unilateral hearing loss is performed by having the subject equate the loudness of a pure tone on one ear with the loudness of a pure tone of identical frequency on the other ear. This procedure is often called 'Fowler's Test' in honor of Dr. E. P. Fowler, whose pioneer efforts in this area (*5,6*) are well known. The purpose of the test is to establish the intensity relations at the two ears, producing equal loudness at various suprathreshold levels.

Over the many years that this test has been employed clinically, two methods for presenting the comparison stimuli to the two ears have been used. In one method, the tones are presented alternately (*3,4,7,8,10-18*). In the second, they are presented simultaneously (*3,8*). In the case of alternate presentation, the subject can make a true loudness comparison as the tone is heard first on one ear, then on the other, then on the first again, and so on. In the case of simultaneous presentation, however, a genuine loudness comparison is not really possible. If the two tones are in phase, they tend to fuse into a single 'phantom image,' whose apparent location within the head varies according to the intensity relations at the two ears. Thus, the subject's response must necessarily take the form of a median-plane localization. He can adjust the binaural intensity relations only until the phantom sound appears to be in the center of his head.

In subjects with normal hearing in both ears, the results obtained by these two methods are apparently, on the average, identical. In other words, if both ears are normal the binaural intensity relations producing equal loudness also produce localization in the median plane.

Hirsh (*9*, p. 242) has pointed out, however, that this situation may not hold in the case of subjects with unilateral hearing loss:

> We have no evidence that these two judgments produce the same results, because we do not know whether, granting that the sounds are in phase at the two ears, central localization requires equal intensity (physical) at the two ears or equal loudness (psychological) at the two ears.

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The initial impetus to the present study was the desire to answer this single question, 'Do the two judgements produce equivalent results in unilateral hearing loss?' Preliminary exploration soon established that the answer was clearly negative. The two judgements did not produce equivalent results in subjects with either unilateral conductive or unilateral sensorineural hearing loss. Discrepancies in results obtained by the two methods of as much as 20 to 30 db were not uncommon, and differences of at least 10 db were consistently observed.

A sequence of experiments was, therefore, designed to permit a systematic evaluation of various parameters which might conceivably either give rise to or affect the discrepancy.

Apparatus and Procedure

Figure 1 shows a simplified block diagram of the apparatus used in all experiments. The output from an audio-oscillator was split and sent into the two channels of an electronic switch (Grason-Stadler, type 816). The two alternating outputs from this device then passed into a switching circuit which permitted the tester to select one of the two experimental conditions. In the 'up' position the output from one channel passed to one phone and the output from the other channel passed to the other phone, resulting in alternate stimulation of the two ears. In the 'down' position, however, the output from only one channel of the electronic switch was split and sent to both phones, resulting in simultaneous stimulation of the two ears. It should be emphasized that the simultaneous stimulation was not continuous but interrupted in time. Furthermore, this simultaneous stimulation was always in phase at the two earphones.

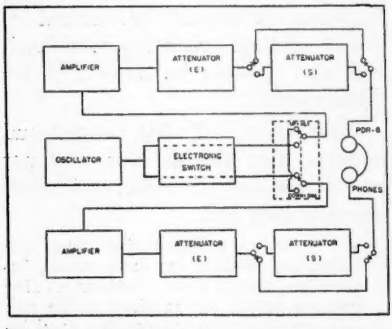

FIGURE 1. Simplified block diagram of apparatus used for alternate and simultaneous binaural balancing.

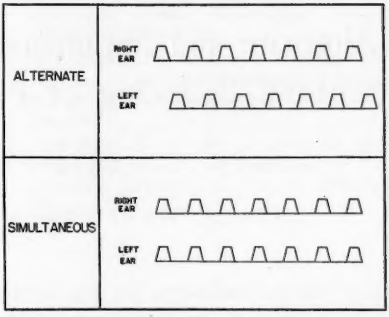

FIGURE 2. Temporal characteristics of alternating and simultaneous stimuli. Rise-decay time not to scale.

All the data gathered in this investigation were obtained using the psychophysical method of adjustment. To accomplish this, provision was made for inserting a 2-db step attenuator in either earphone line by which the subject could adjust the intensity of the signal at that phone to achieve the desired match. Each of these 2-db step attenuators had a total range of 60 db. Furthermore, by means of the attenu-

ator, designated 'E' in either line, the experimenter was able to introduce arbitrary attenuation between successive matches in order to minimize positional cues on the subject's attenuator dial.

Figure 2 illustrates the temporal relations of the stimuli to each ear for both alternate and simultaneous conditions. The rise-decay time of each short tone was 50 msec and the total duration was ordinarily 1000 msec.

A complete test run at a particular frequency required that the subject make six intensity adjustments, three under alternate stimulation and three under simultaneous stimulation. For the alternate matches the subject was instructed to adjust his attenuator until the tones were equally loud in the two ears. For the simultaneous matches he was instructed to adjust his attenuator until the sound image was in the center of his head. The experimenter varied the attenuation in the variable channel by an arbitrary amount between successive matches, and a match was defined as the arithmetic mean of the three separate intensity adjustments for a particular condition. A minimum rest period of 20 seconds occurred between all successive matches.

In all of the investigations summarized under the section *Experimental Findings*, successive conditions (that is, alternate vs. simultaneous) occurred in random order. However, in the application of the technique to clinical patients, this procedure was abandoned in favor of a sequence in which the three alternate matches were made first, the three simultaneous matches second.

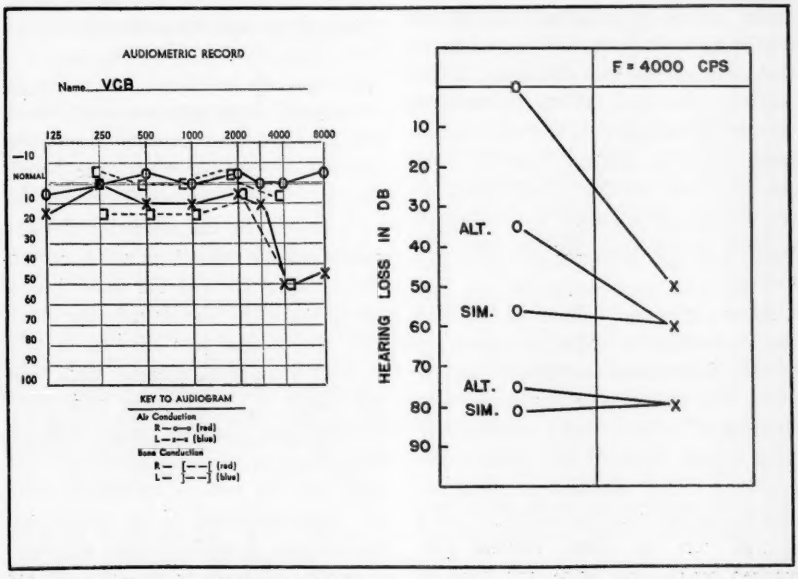

FIGURE 3. Audiogram and binaural balance results in a case of unilateral sensorineural loss presumably due to excessive noise exposure.

Preliminary Observations

The systematic application of these testing techniques to subjects with unilateral hearing loss quickly revealed that the two methods do not, indeed, yield the same results. Figure 3 shows a set of findings typical of results obtained in unilateral sensorineural losses with recruitment. The subject was a 34-year-old male with a high frequency loss on the left ear, presumably due to excessive noise exposure (acoustic trauma). When a 4000-cps tone was fixed at a sensation level of 10 db on the impaired ear, the subject adjusted the tone on the normal ear to a sensation level of 35 db, in the alternate condition, but to a sensation level of 55 db in the simultaneous condition.

The absolute magnitude of the difference between the two methods varies widely from subject to subject but in unilateral loss with recruitment the direction of this difference is invariably the same. When the subject adjusts the intensity of the tone on the normal ear to match a tone of fixed sensation level on the impaired ear, he requires greater intensity for the simultaneous match than for the alternate match.

After repeated observations had demonstrated the apparent generality of this phenomenon, a series of experiments was designed to explore various parameters which might conceivably shed further light on this curious discrepancy. These experiments, summarized in the following sections, involved normal ears in quiet, normal ears masked by thermal noise, and genuine sensorineural loss with recruitment.

Experimental Findings

Effect of Judgement Time. In reflecting on possible factors which might underly the consistent observation of a relatively large discrepancy between simultaneous and alternate matches in unilateral losses with recruitment, it was first hypothesized that the length of time taken by the subject in making each single judgement might be a significant variable. It seemed possible that the train of successive signals on the impaired ear might give rise to a progressive fatigue or adaptation effect during the time that the subject was attempting to make a judgement even though the stimulus was periodically interrupted, and that such a phenomenon might exert a differential effect on the two types of response. Specifically, it was suspected that such a progressive fatigue or adaptation effect would influence the alternate judgement more than the simultaneous.

To test this hypothesis, three groups of subjects were asked to make both alternate and simultaneous judgements under four conditions. In one condition only 15 seconds were allowed for each match. In the second and third conditions 35 and 55 seconds, respectively, were allotted for each judgement, while in the fourth condition (X), the subject was allowed to take as much time as he pleased. Each subject made three alternate and three simultaneous matches under each of these four experimental conditions. The order of the various conditions over the entire sequence of 24 judgements was random. A 4000-cps tone was fixed at an SPL of 90 db on the impaired ear and the subject varied the intensity on

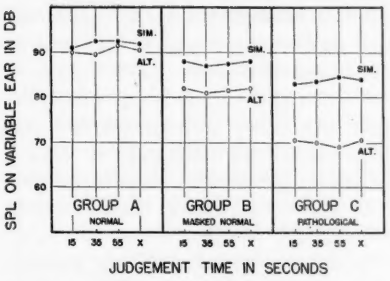

FIGURE 4. Effect of judgement time on alternate and simultaneous matches in normal, masked normal, and pathological ears.

the unimpaired ear to the desired criterion. Figure 4 shows the results obtained in each of three groups of 10 subjects. The ordinate is the mean sound pressure level on the variable ear necessary to achieve the desired criterion.

Group A subjects had normal hearing in both ears. It is clear that the four conditions of judgement had no significant effect on either the alternate or simultaneous matches. There was a slight discrepancy between the alternate and simultaneous curves, but the difference was not statistically reliable.

Group B subjects also had normal hearing in both ears, but thermal noise at an overall SPL of 80 db in one ear created an artificial unilateral loss of about 60 db. Again, the length of time allowed for the judgement affected neither the alternate nor the simultaneous match, but here there was a difference of about 6 db between the two types of judgement at all four judgement times.

Group C consisted of 10 subjects with true unilateral hearing loss of the sensorineural (perceptive) type with loudness recruitment, as defined by the alternate matches. The average loss at the experimental frequency (4k) was 48 db. Here the average discrepancy between simultaneous and alternate matches was about 13 db but again the length of time allowed per judgement had no particular effect.

These findings suggest that the length of time the stimulus train is on continuously in either ear does not seem to be an important variable. In all subsequent experiments, therefore, the subject was allowed to take as much time as he pleased to make any single judgement.

Effect of Fixed Ear. Another variable in this judgemental situation, and one that has received remarkably little attention in the clinical literature, is the question of which is the fixed and which is the variable ear. In other words, does it matter whether the subject adjusts the intensity on the good ear to match a tone of fixed intensity on the bad ear, or whether he varies the intensity on the bad ear to match a fixed reference on the good ear? In order to explore this variable, four experienced subjects with unilateral losses made both alternate and simultaneous judgements first with the reference tone fixed on the bad ear, then with the reference tone fixed on the good ear at the exact intensity which had been equated to the fixed reference on the bad ear. For example, if the reference was fixed at a sensation level of 20 db on the bad ear, the subject might adjust the intensity of the variable tone on the good ear to a sensation level of 60 db. The reference tone was then immediately fixed at 60 db on the good ear and the subject adjusted the intensity on the bad ear, the purpose being to determine whether on the bad

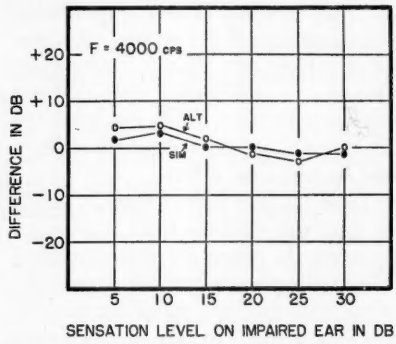

FIGURE 5. Effect of varying fixed ear on alternate and simultaneous matches in true unilateral losses.

ear he would go back to the 20-db level at which he had started.

All judgements in this group were made at a test frequency of 4000 cps. Six sensation levels on the impaired ear (5, 10, 15, 20, 25, and 30 db) were employed.

Results here were totally negative. Figure 5 shows the mean discrepancy from an exact return, for both alternate and simultaneous matches, as a function of the sensation level of the fixed tone on the impaired ear. A positive discrepancy means that the rematch was more intense than the original level, a negative discrepancy that it was less intense. No appreciable effect is apparent in either curve.

In order to explore this issue further, a similar procedure was followed for 10 subjects with normal hearing, but with thermal noise, at an overall SPL of 80 db, creating an artificial loss on one ear. At the test frequency of 4000 cps, four sensation levels on the masked ear (5, 10, 15, and 20 db) were explored. Results again were negative. Figure 6 shows the mean discrepancy from an exact return, for both alternate and simultaneous matches, as a function of the sensation level of the fixed tone on the masked ear. Again, no systematic effect of any appreciable magnitude was apparent.

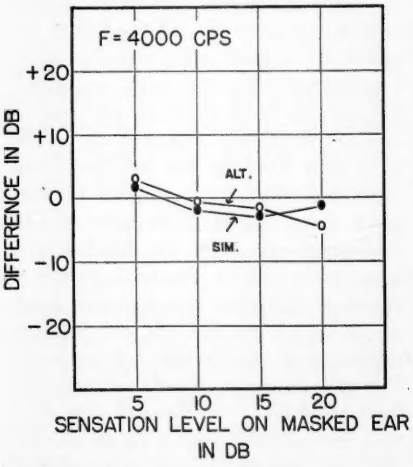

FIGURE 6. Effect of varying fixed ear on alternate and simultaneous matches in monaurally-masked normals.

These results suggested that it was irrelevant to which ear the fixed tone was applied in either alternate or simultaneous binaural balancing. In all subsequent investigations, therefore, the signal intensity was routinely fixed on the impaired ear and varied on the unimpaired ear to the desired criterion.

Effects of Signal Duration and Sensation Level. In all of the experiments reported above, the duration of each short tone, whether delivered alternately or simultaneously to the two ears, was exactly 1000 msec. It seemed possible that the factor of signal duration might give rise to the observed discrepancy by exerting a differential effect on the two types of judgements. On the basis of Hood's (*11*) discussion

of on-effect and relapse in sensory stimulation, it was hypothesized that varying the short-tone duration might influence the alternate judgement but not the simultaneous judgement since the former is presumably based on the total loudness experience integrated over the entire duration while the latter might be based solely on the initial or leading portions of stimulus envelopes.

To investigate this hypothesis in the case of actual ear pathology, the same four highly experienced subjects with true unilateral loss made alternate and simultaneous judgements at six sensation levels (5, 10, 15, 20, 25, 30 db) on the impaired ear at the test frequency of 4000 cps, for each of three signal durations (500, 1000, and 2000 msec).

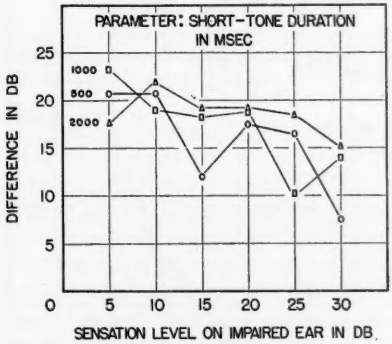

FIGURE 7. Effect of short-tone duration on difference between alternate and simultaneous matches in true unilateral losses.

There appeared to be no systematic duration effect (see Figure 7) within the range of signal durations employed. There was, however, a definite trend associated with sensation level. The magnitude of the discrepancy between alternate and simultaneous matches was maximal at low sensation levels and

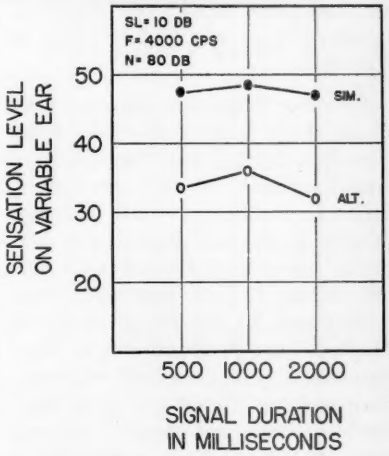

FIGURE 8. Effect of short-tone duration on alternate and simultaneous matches at a sensation level of 10 db in monaurally masked normals.

showed a slight but progressive decrease as the sensation level increased. This dependence on sensation level appears to be quite general. It has occurred throughout the present series of experiments, both in true unilateral hearing loss and in monaurally masked normals. The largest discrepancies between alternate and simultaneous matches appear at relatively low sensation levels.

In order to affirm that duration also exerted no significant effect in the case of the normal ear masked by noise, 10 subjects with normal hearing made alternate and simultaneous matches at 4000 cps in the presence of thermal noise at an overall SPL of 80 db in one ear. Matches were made for each of the three durations (500, 1000, and 2000 msec) at a single sensation level of 10 db on the masked ear. Figure 8 illustrates these results. Again, no systematic duration effect was evident. In

all subsequent exploration, therefore, signal duration was held constant at 1000 msec.

Effects of Frequency, Sensation Level, and Noise Level in Masked-Normal Ears. In order to extend the search for factors related to the discrepancy between simultaneous and alternate matches in the noise-masked ear, four highly experienced subjects with normal hearing in both ears were extensively tested. Six sensation levels (5, 10, 15, 20, 25, and 30 db) at each of three frequencies (250, 1000, and 4000 cps) were explored in quiet and under three levels of monaural thermal masking noise (40, 60, and 80 db, overall SPL). Short-tone duration was held constant at 1000 msec, and the fixed tone was always presented to the masked ear. The order in which successive conditions were presented was separately randomized for each subject.

Figure 9 shows the results obtained at three of the six sensation levels explored (10, 20, and 30 db). The ordinate again represents the intensity difference on the variable ear. A positive difference means that more intensity was required on the variable ear for the simultaneous than for the alternate match.

Here a surprising result is noted. In previous explorations the test frequency

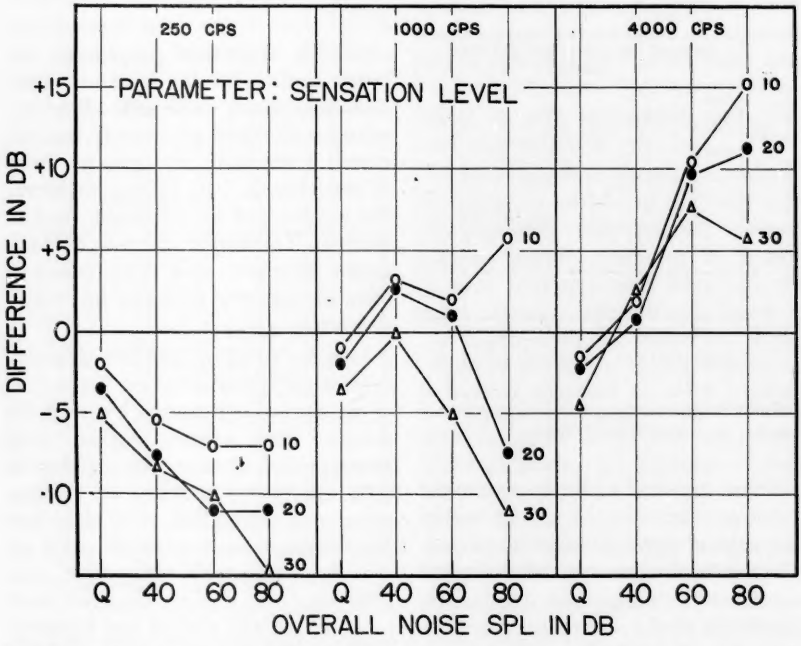

FIGURE 9. Effects of frequency, sensation level, and noise level on difference between alternate and simultaneous matches in monaurally-masked normals.

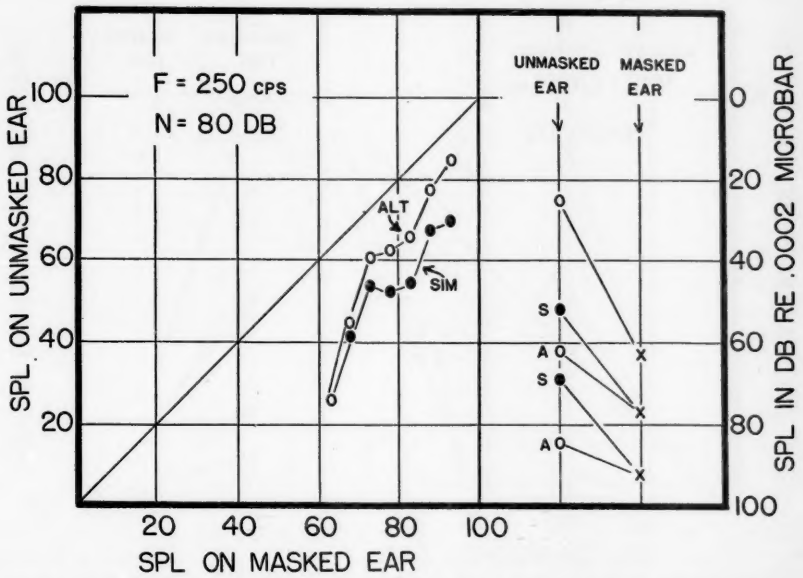

FIGURE 10. Alternate and simultaneous matches at 250 cps in monaurally-masked normals. Noise at an overall sound pressure level of 80 db. On the right half of the figure, the data for sensation levels of 15 and 30 db are replotted in the form of the Fowler-type laddergram.

had been confined almost exclusively to 4000 cps and positive differences were the rule. In Figure 9 there is the expected positive difference at 4000 cps but a totally opposite effect at 250 cps. At 4000 cps the positive difference increases with increasing noise level and decreases with increasing sensation level. At 250 cps, however, all differences are negative (more intensity on variable ear for alternate than for simultaneous) and the negative difference becomes larger as either noise level or sensation level is increased.

An intermediate condition seems to be reached at 1000 cps. The difference is positive at low sensation levels but negative at higher levels. At low sensation levels the function relating difference to noise level behaves like the set of curves for 4000 cps. At higher levels, however, the function rapidly descends into the negative-difference region as noise level increases, in this respect behaving more like the curves for 250 cps. Figures 10, 11, and 12 replot the data of Figure 9 in two other conventional modes in order to illustrate these generalizations more concretely.

The curious manner in which the difference appeared to depend upon frequency prompted an extensive search for an explanation in terms of an artifact of instrumentation. None could be found.

Interaural Threshold Disparity. In order to demonstrate that the consistently observed differences between alternate and simultaneous matches in

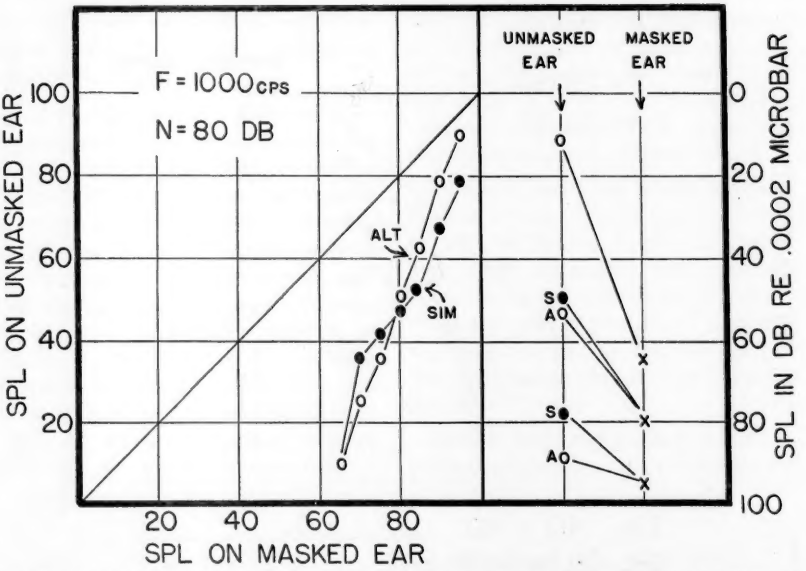

FIGURE 11. Alternate and simultaneous matches at 1000 cps in monaurally-masked normals. Noise at an overall sound pressure level of 80 db. On the right half of the figure, the data for sensation levels of 15 and 30 db are replotted in the form of the Fowler-type laddergram.

patients with unilateral hearing loss were not due simply to the fact of unbalanced acuity between the two ears, an artificial unilateral loss was created in seven normal hearers by plugging one ear with a wax-impregnated cotton pellet (Flent). Figure 13 shows the difference between alternate and simultaneous matches at two frequencies (1000 and 4000 cps) at each of six sensation levels on the plugged ear (5, 10, 15, 20, 25, and 30 db).

As in the case of bilateral normal hearing, there is no marked difference here between the results obtained by the two methods. These results strengthen the conviction that the discrepancy between alternate and simultaneous matches in both masked normal and genuinely diseased ears is apparently related to the nature of the process producing the unilateral loss.

Clinical Findings

In response to the challenge imposed on auditory theory by the experimental findings summarized above, both alternate and simultaneous matches were routinely obtained on all patients with unilateral hearing loss seen in the Northwestern University Hearing Clinics over a two-year period. The exact technique employed was based on the findings cited above. Tonal duration was held constant at 1000 msec. The tone was always fixed on the impaired ear and varied on the unimpaired ear. Each match was defined as the average of three separate intensity adjustments with varying arbitrary attenuation in-

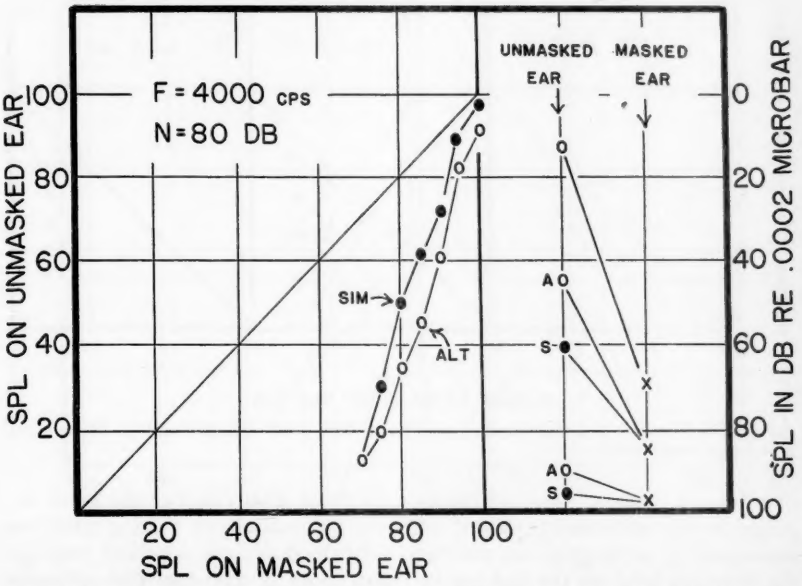

FIGURE 12. Alternate and simultaneous matches at 4000 cps in monaurally-masked normals. Noise at an overall sound pressure level of 80 db. On the right half of the figure, the data for sensation levels of 15 and 30 db are replotted in the form of the Fowler-type laddergram.

troduced by the tester between successive matches. Finally it was found to be desirable in the clinical context to have the patient execute the three alternate judgements first and the three simultaneous judgements second, rather than to follow a random sequence as was the practice in all of the experimental studies. Sensation levels of 10, 20, 30, and 40 db on the impaired ear were tested whenever possible. Attention was furthermore concentrated on the three frequencies of 250, 1000, and 4000 cps.

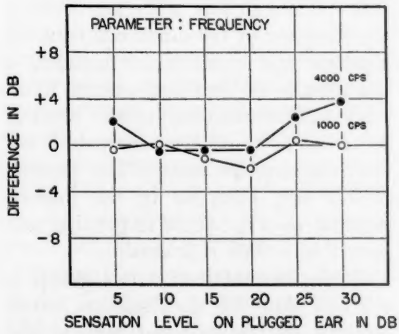

FIGURE 13. Difference between alternate and simultaneous matches at 1000 and 4000 cps in monaurally-plugged normals.

Relationship to Loudness Recruitment. As a first step in the analysis of these clinical data, all patients with sensorineural loss were divided into two groups, those with loudness recruitment and those without loudness recruitment. No conductive losses were included in this analysis. Loudness recruitment was defined by the alternate

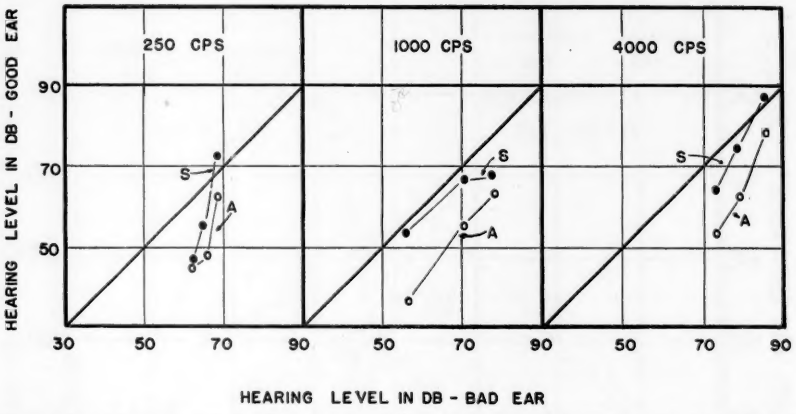

FIGURE 14. Alternate and simultaneous matches at 250, 1000, and 4000 cps in 34 unilateral losses with recruitment.

matches. A patient was arbitrarily placed in the recruitment group if the sensation level on the good ear exceeded the sensation level on the bad ear by at least 15 db at every sensation level tested. All patients who did not meet this criterion were placed in the nonrecruitment group. Suitable data were available on a total of 46 patients with unilateral loss. Of this number, 34 had loudness recruitment, 12 did not. For a variety of reasons not every patient could be tested at every frequency (250, 1k, 4k) or at every sensation level (10, 20, 30, 40 db). Furthermore, insufficient data were available at 4000 cps in the nonrecruitment group to warrant any generalization at this frequency. Therefore only results at 250 and 1000 cps are presented for the nonrecruitment group.

Figure 14 shows the mean alternate and simultaneous matches at three frequencies for the 34 patients with recruitment. The mean threshold hearing level on the bad ear in this group was 38 db at 250 cps, 46 db at 1000 cps, and 56 db at 4000 cps. For the good ear, the mean threshold hearing level was −2.5 db at 250 cps, −5 db at 1000 cps, and 10 db at 4000 cps. The difference between ears at a test frequency was never less than 20 db, never greater than 70 db.

It is interesting to observe initially that the results displayed in Figure 14 are quite unlike those obtained in the case of monaurally masked normal ears (Figures 9, 10, 11, 12). In the case of true unilateral loss with recruitment, the direction of the difference between alternate and simultaneous matches is the same at all three frequencies. In all cases the simultaneous match requires more intensity on the unimpaired ear than the alternate match. The reversal at 250 cps, observed in the masked normals, does not occur in genuine unilateral loss with recruitment.

Of further interest in this group is the fact that the simultaneous match requires essentially equal SPL at the two ears. The discrepancy between alternate and simultaneous matches de-

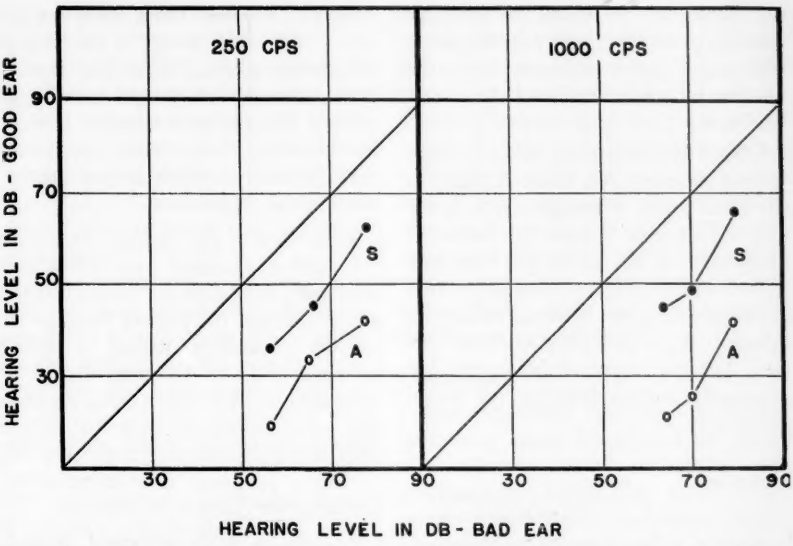

FIGURE 15. Alternate and simultaneous matches at 250 and 1000 cps in 12 unilateral losses without recruitment.

rives from the fact that the alternate match does not require quite as much SPL on the unimpaired ear as on the impaired but the simultaneous match does. This relationship holds up quite well at all sensation levels tested.

The previously cited observation of a decrease in the discrepancy between simultaneous and alternate matches as sensation level increased is simply a consequence of the fact that recruitment (alternate matches) increases with sensation level (that is, the SPL on the unimpaired ear tends closer and closer to the SPL on the impaired ear, whereas the simultaneous match requires equal SPL at any sensation level).

Figure 15 shows the results obtained in the 12 subjects without recruitment. Only data for 250 cps and 1000 cps are presented. The mean threshold hearing level on the bad ear in this group was 44 db at 250 cps and 52 db at 1000 cps. The mean threshold hearing level on the good ear was 2.5 db at 250 cps and −2 db at 1000 cps. In this group the difference between ears at any test frequency ranged from 25 db to 75 db.

Figure 15 shows that in patients without recruitment the difference between alternate and simultaneous matches is even greater than in patients with recruitment. The alternate matches simply reflect the absence of recruitment on the bad ear. The simultaneous matches, on the other hand, are displaced upward to an astonishing degree. Unlike the case for patients with recruitment, however, localization in the median plane does not require equal SPL at the two ears. In patients without recruitment, the simultaneous match requires somewhat more intensity on the bad ear than on the good

ear. However, the interaural intensity relations producing median-plane localization are quite different from the relative intensities required for equal loudness.

One of the important clinical implications arising from these findings is the inescapable conclusion that loudness recruitment cannot be measured by presenting stimuli to the two ears simultaneously. Figure 15 clearly demonstrates that equal loudness cannot be inferred from median-plane localization. The two types of judgement are apparently independent and not interchangeable.

Discussion

The results summarized above clearly show that in unilateral sensorineural hearing loss, either with or without recruitment, the interaural intensity relations required to produce equal loudness are not the same as the intensity relations required to produce localization in the median plane. Furthermore, the discrepancy between the two types of judgement is greater in patients without than in patients with recruitment.

A possible explanation for this curious set of findings lies in recent studies by Deatherage, Eldredge, and Davis (*1*) on the latency of the action potential (AP) in guinea pigs, and by Deatherage and Hirsh (*2*) on the localization of clicks.

These investigations suggest a physiological mechanism for intracranial localization essentially independent of the parameters of the neural discharge pattern presumably important for the judgement of loudness. Specifically, it is suggested that localization is based primarily on latencies of the APs at the two ears. When these latencies are equal, the sound image is referred to the median plane. When they are unequal, the sound image is referred toward the ear with shorter latency. Furthermore, it was shown that latency could remain constant in the face of varying AP magnitude.

If, in view of this finding, one makes the further plausible assumption that loudness is related to AP magnitude but not to latency, the present findings are entirely reasonable. Indeed, it would be remarkable to find any degree of agreement at all between equal loudness and median-plane localization. In the light of the papers cited above, the following is proposed as a tentative explanation for the present findings.

In patients with unilateral sensorineural loss accompanied by recruitment, the lesion is probably in the cochlea. The cochlear lesion, by a mechanism as yet unknown, affects the intensity-loudness function on the bad ear in such a way that the patient must raise the intensity on his good ear to an inordinate degree in order to achieve equal loudness at the two ears. But this 'recruitment' of loudness, especially at low sensation levels on the bad ear, is never quite 'complete.' It does not take quite as much SPL on the good ear as on the bad ear for equal loudness.

In spite of its effect on threshold acuity and on the intensity-loudness function, the cochlear lesion has no effect on the latency between the cochlear microphonic response (CM) and the action potential response (AP). This latency is primarily determined by the effective intensity reaching the cochlea and is not materially altered by the presence of cochlear pathology.

Hence, median-plane localization, based primarily on equivalent AP latencies in the two ears, requires essentially equal SPL in the two ears. Thus the discrepancy between alternate and simultaneous matches derives from the extent to which equal loudness does not require equal SPL at the two ears (that is, the extent to which recruitment is 'incomplete').

In patients with unilateral sensorineural loss without recruitment, the lesion is probably in the eighth nerve rather than the cochlea. In the present series of 12 cases, five were actually surgically confirmed acoustic neurinoma. The eighth-nerve lesion profoundly affects the magnitude of AP but, again, has no effect on the latency between CM and AP. Because of its effect on AP magnitude on the bad ear, equal loudness requires essentially equal sensation levels (that is, no recruitment). Median-plane localization, however, demands equal latencies irrespective of relative AP magnitudes, and ideally this, again, is achieved by equal SPL at the two ears. However, a secondary effect of the eighth-nerve lesion is a reduction in velocity of neural transmission on the bad ear. In order to compensate for this neural delay on the bad ear, the patient must reduce the intensity on the good ear to achieve median-plane localization. This reduction is small, however, in comparison with the attenuation required on the good ear in order to make the sounds equally loud. Hence, a relatively large discrepancy between alternate and simultaneous judgements appears.

In the case of monaurally-masked normal ears the explanation proposed above for unilateral losses with recruitment may be invoked to explain the results at 4000 cps. The results at 250 cps may be explained by assuming that the noise lengthens the CM to AP latency for the 250 cps tone in the face of normal or even abnormally great AP magnitude. Intensity must, therefore, be reduced on the good ear to a substantial degree in order to localize the tone in the median plane, relative to the good-ear intensity producing equal loudness. Such an explanation is not incompatible with the findings of Deatherage and Hirsh (*2*).

Summary

The interaural intensity relations producing equal loudness when pure tones were presented alternately, and median-plane localization when they were presented simultaneously to the two ears, were studied in normals, monaurally masked normals, and patients with unilateral sensorineural hearing loss, both with and without loudness recruitment.

Results indicate that the two types of judgement do not yield equivalent results. In general, median-plane localization requires more nearly equivalent SPLs at the two ears than does equal loudness but there are important qualifications.

A significant clinical implication arising from these findings is that loudness recruitment must always be measured by alternate, never by simultaneous, stimulation of the two ears.

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MMPI Differences between Parents of Children with Cleft Palates and Parents of Physically Normal Children

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The personality and psychological adjustment of the parents of children with cleft palates and lips are important for both theoretical and practical reasons. While little is known specifically at this time about the development and later adjustment of children with cleft palates, it can be assumed from studies of normal children and of children with other types of speech disorders (*4*, *6*, 7, *8*) that the parent-child interaction is a crucial one. Any theoretical understanding of the child and his development, when that child has a cleft palate, would involve a study of how the parents react to the initial knowledge of this anomaly of the speech mechanism, how these reactions change in time, how these reactions affect the nature of the parent-child relationship, and how all of these reactions are related to the speech adequacy and overall adjustment of the child. In a more practical vein, the speech clinician must decide if the parents of a child with a cleft palate are sufficiently well adjusted to be helpful in the planning and execution of a remedial program for that child. Despite the apparent importance of parental personality and adjustment in the understanding and management of the child who has a cleft palate, a search of the literature has failed to reveal any systematic study of such parents.

The purpose of the present study was to compare the personality and adjustment of a group of parents of children with cleft palates and lips and a group of parents of physically normal children by means of an objective test, the Minnesota Multiphasic Personality Inventory (MMPI). Goodstein and Dahlstrom (*2*), Goodstein (*1*), and Grossman (*3*) have used the MMPI in a similar way to evaluate the personality and adjustment of the parents of stutterers as have Williams (*12*) and Liverant (*5*) in investigating the adjustment of parents of children who have cerebral palsy and those who are emotionally disturbed.

Because of space limitations it is not possible to discuss here the administration, scoring, or interpretation of the MMPI. The reader is referred to the recent volume by Johnson and others (*4*, pp. 181-186) for a brief description or to the volume by Welsh and Dahlstrom (*11*) for a more extensive description.

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Procedure

As part of a large-scale, intensive investigation of the factors related to the adjustment of individuals with cleft lips and palates, the voluntary participation of 175 families with a child having a cleft lip or palate or both was obtained. These experimental families were drawn from seven midwestern states, predominantly from Iowa and Illinois. The children were white, ranged in age from infancy through 16 years of age, and had no obvious motor involvement. In the experimental group were included only those families in which the mothers agreed to accompany the child to the University of Iowa Medical Center for interview and study. Where appropriate, the families were reimbursed for their expenses; in no case was any charge made for the psychological or medical procedures involved.

The routine administration of the booklet form of the MMPI was part of the standard experimental procedure followed with each parent who had agreed to participate in the overall study. While it had been planned to obtain an MMPI profile from each parent, this goal was not realized because of a number of uncontrollable factors such as lack of time, inability to read, and refusal to cooperate. MMPI profiles, however, were obtained from 170 mothers and 157 fathers in the experimental group. An inspection of the other data did not suggest that those parents who had failed to complete the MMPI were different in any obvious ways from the parents for whom profiles were obtained. The MMPI was handscored for the usual four validity and nine clinical scales as well as for the Taylor Manifest Anxiety Scale (*A* scale) (*9*).

It was decided, because of the difficulty and expense involved, not to obtain a control group for this portion of the study. Instead, the MMPI profiles from a control group in a recent study of the onset of stuttering (*2*) were used. This control group had been obtained by appeals for volunteers made to PTA's, church groups, and others in the same geographic region as the cleft palate experimental group and there was no a priori reason not to regard this group as an adequate control for this aspect of the investigation. All of these parents had reported that their children were, to the best of their knowledge, physically normal and, further, the interviewers were not able to observe any obvious physical handicap in these children.

Results

A comparison of the means of the fathers with means of the mothers in the experimental group and of the means of the fathers with the means of the mothers in the control group gave no evidence of any differences in the scores, so the data from the two sexes were combined. The only exception to this finding was on the Masculinity-femininity (*Mf*) scale, on which both groups of fathers had significantly higher ($p < .01$) mean *T* scores than both groups of mothers (higher scores on this scale indicate greater opposite-sex interest and identification); there were, however, no significant differences between the experimental and control groups and the data were, therefore, combined in this case as well.

The means and standard deviations

TABLE 1. Means and standard deviations (approximate values, from coded scores) of the MMPI scores for the experimental and control groups of parents, and the significance levels of the differences between the means (t tests for mean differences as well as significance levels for these differences were based on the more precise coded score values rather than on the values reported in this table).

*Scale**	*Experimental Group N=327*		*Control Group N=200*		*Significance Level*
	Mean	*SD*	*Mean*	*SD*	
?	5.3	6.7	5.8	4.6	ns†
L	5.2	1.7	3.6	1.8	.01
F	3.2	1.4	2.8	1.8	ns
K	15.4	4.9	16.9	4.8	.01
Hs	51.7	9.7	51.0	7.4	ns
D	52.8	8.9	52.4	9.2	ns
Hy	54.9	8.9	56.1	7.7	ns
Pd	52.7	8.8	54.8	9.0	.01
Mf[d]	51.7	8.6	52.7	10.1	ns
Pa	52.8	8.3	52.3	6.8	ns
Pt	51.7	8.4	51.9	7.7	ns
Sc	49.3	8.5	52.2	7.8	.01
Ma	50.0	9.8	51.2	9.1	ns
A	13.8	7.3	11.8	6.9	.01

*The scores on the clinical scales (*Hs, D, Hy, Pd, Mf, Pa, Pt, Sc, and Ma*) are in T-score units; all the others are expressed in raw-score units, K-scale corrections included where appropriate.
†Not significant.

on the 14 MMPI scales for the experimental and control groups are presented in Table 1 together with the significance level of the differences between the group means.

On the four validity scales the experimental group mean was significantly higher ($p < .01$) on the Lie (L) scale and significantly lower ($p < .01$) on the K scale than the control. While higher scores on both these scales indicate defensiveness on the part of the test taker, in neither case are the differences or the absolute values of the means large enough to suggest invalid profiles. There were no significant differences on the *?* and *F* scales.

On six of the nine clinical scales the experimental group mean was lower than that of the control group, with higher scores on the clinical scales typically interpreted as symptomatic of maladjustment. Two of these differences, on the Psychopathic Deviate (*Pd*) and on the Schizophrenia (*Sc*) scales, were statistically significant ($p < .01$). The experimental group mean was higher on three clinical scales, Hypochondriasis (*Hs*), Depression (*D*), and Paranoia (*Pa*), but none of these differences approached statistical significance.

The experimental group mean was significantly higher ($p < .01$) than the control group mean on the *A* scale, suggesting that these parents admitted to more manifest anxiety symptoms than did the control group parents. In this respect the experimental group parents were quite similar to the par-

ents of stuttering children (*1*), whose mean on the *A* scale was 14.3 (*SD*, 7.6).

The number of clinical scale values above 70 can be used as a gross measure of adjustment for an individual since 70 represents the usual cutting score indicating an 'abnormal' response. Of the 170 mothers in the experimental group, only 14% had one or more clinical score values above 70 while only 7% had two or more clinical scale scores above 70. For the 100 mothers in the control group these figures were 8% and 3%, respectively. Of the 157 fathers in the experimental group, 19% had one or more clinical scale scores above 70 and only 5% had two or more scores above 70. The 100 fathers in the control group showed comparable figures of 20% and 5%. Thus there is a marked similarity between the two groups of parents with respect to this index of adjustment.

The relative frequencies with which each clinical scale appeared as the highest *T*-score value in the individual profiles (*10*) are presented in Table 2. The differences between the obtained frequencies were then analyzed by means of the chi-square test for a two-by-nine table. Since there were significant differences between the sexes (for the combined group the chi-square value was 38.07, $df = 8$, $p < .01$), mothers of the experimental group were compared with mothers of the control group, the difference being statistically significant (chi square = 21.71, $df = 8$, $p < .02$); the comparison of fathers of the experimental group with fathers of the control group also yielded significant differences (chi square = 21.71, $df = 8$, $p < .01$). In the mothers' profiles (Table 2) the *Mf* and *Pa* scales were more frequently the highest in the experimental group while the *Pd* scale was more frequently the highest scale in the control group. In the case of the fathers' profiles it can be noted that the *Hs* and *D* scales were the more frequent highest scales for the experimental group while the *Hy*, *Pd*, and *Mf* were the more frequent highs for the control group.

The relative frequencies with which each clinical scale was found to be the second highest *T*-score value in the individual profiles are presented in

TABLE 2. Relative frequency of the highest score in the individual profiles for the two groups of subjects.

MMPI Clinical Scale	*Experimental Group*			*Control Group*		
	Mothers N=170	*Fathers N=157*	*Both N=327*	*Mothers N=100*	*Fathers N=100*	*Both N=200*
Hs	4	12	16	3	1	4
D	14	16	30	18	10	28
Hy	22	9	31	27	17	44
Pd	12	9	21	22	18	40
Mf	16	20	36	6	27	33
Pa	16	8	24	7	4	11
Pt	3	4	7	7	5	12
Sc	3	4	7	5	3	8
Ma	10	18	28	5	15	20
Total	100	100	200	100	100	200

TABLE 3. Relative frequency of the second highest score in the individual profiles for the two groups of subjects.

MMPI Clinical Scale	*Experimental Group*			*Control Group*		
	Mothers N=170	*Fathers N=157*	*Both N=327*	*Mothers N=100*	*Fathers N=100*	*Both N=200*
Hs	12	3	15	9	2	11
D	13	16	29	6	13	19
Hy	18	27	45	20	18	38
Pd	16	13	29	14	16	30
Mf	11	14	35	13	16	29
Pa	9	11	20	12	9	21
Pt	11	4	15	8	6	14
Sc	4	5	9	7	9	16
Ma	6	7	13	11	11	22
Total	100	100	200	100	100	200

Table 3. The differences between the obtained frequencies were again analyzed by means of the chi-square test for a two-by-nine table. Again there were significant differences between the total male and the total female groups (chi square=21.68, $df = 8$, $p < .01$); therefore, the data from the two sexes were analyzed separately. In the case of the secondary high points, however, there were no significant differences either between mothers of the experimental and control groups (chi square $= 8.05$, $df = 8$) or between fathers of the experimental and control groups (chi square $= 6.78$, $df = 8$).

Discussion

The most noteworthy finding was the failure to demonstrate any striking differences between the parents of the children with cleft palates (experimental group) and the parents of children without clefts (control group). Although certain differences between the two groups were statistically significant and deserve consideration, the overall impression left by the results is that if important personality differences exist between these groups, they are not reflected by their MMPI scores. Certainly the small absolute differences between the means and the large amount of overlap between the two sets of scores would limit any differential statements regarding personality or adjustment characteristics of these two groups of parents.

It is important to note that not only are the two sets of parents very similar to each other but both are very similar to the original Minnesota standardization group (*11*). The highest clinical scale mean for the experimental group was 54.9 on the *Hy* scale, which represents a deviation of less than one-half a standard deviation from the expected score of 50.0 for a group of normally adjusted persons. The highest clinical scale mean for the control group was 56.1, also on the *Hy* scale. While some of these mean values may be of statistical significance, they are not, in all probability, psychologically important.

It is considerably more reasonable to attribute such small differences to sampling factors than to assume 'real' differences between the groups used in this study and the standardization group.

The absence of abnormality in these mean profiles is even more apparent when they are compared with the mean profiles of various neurotic and psychotic groups (*11*) and of parents of emotionally disturbed children (*5*). Each of these latter groups has a more or less characteristic mean profile with very marked peaks and valleys, differing greatly from the results obtained in the present study. Such comparisons offer strong support for the contention that the parents of the experimental group are, for the most part, essentially normal persons who differ little, if at all, from the group of normal adult Minnesotans who comprised the standardization sample. The results of the present study are also much like those of Goodstein and Dahlstrom (*2*), Goodstein (*1*), and Grossman (*3*), who, using similar research designs, were unable to establish significant differences between parents of children who stutter and parents of children who do not, and like those of Williams (*12*), who found no differences between parents of children with cerebral palsy and parents of physically normal children.

While the results of the present study do not support the notion that the parents of children with cleft palates and parents of physically normal children are very different from each other, it should be recalled that five of the 14 mean differences were statistically significant. Although the absolute differences were quite small, such differences require further comment. Two of these significant differences occurred on the validity scales with the experimental group higher on the *L* scale and the control group higher on the *K* scale. Higher scores on these two scales are usually interpreted as indicating defensive attitudes, but the direction of the differences suggests that the experimental group shows more obvious defensive attitudes and the control group more subtle defensive attitudes. Both groups, however, were well within the normal range of such attitudes and these differences probably reflect slight differences in socioeconomic class between the two groups of subjects. The control group was recruited from various community organizations which tend to attract middle-class parents, while the experimental group was seen in a state-supported medical center which tends to attract more families of a lower socioeconomic class. These selection factors may have produced a slightly higher socioeconomic level in the control group which, in turn, is reflected in the mean validity scale scores.

The comparison of the highest scores in the individual profiles also yielded significant results with the experimental group mothers more frequently showing *Mf* and *Pa* as the highest, the control group mothers' codes having *Pd* as the high more frequently. The experimental group fathers showed *Hs* and *D* more frequently as the high while the control group fathers showed *Hy*, *Pd*, and *Mf* more frequently. These results are somewhat difficult to interpret but, in any event, there is no suggestion of any greater pathology on the part of the parents in the experimental group. These differences may also be a function of the socioeconomic

differences between the two groups. In order to avoid the issues raised by this possibility, the remainder of the large scale study of the psychological differences in children with cleft palates and their parents will not use existing control data but, rather, will utilize a new control group, matched in socioeconomic status to this particular experimental group.

Two of the significant mean differences were on the *Pd* and *Sc* scales. In both cases, however, the control group mean was the significantly higher one, indicating more deviant scores in the control group; the small absolute differences coupled with the large sample size suggest that sampling differences constitute the most likely explanation of the obtained results.

The experimental group parents were significantly higher on the Anxiety (*A*) scale than were those of the control group. Certainly the admission of greater anxiety and tension on the part of the parents of the children with cleft palates is not surprising. The relationship of this parental anxiety or adjustment to later childhood management of these children is a matter for further study.

One more line of evidence about the essential normalcy of these parents of cleft palate children was the finding that only approximately 15% of the experimental group had one or more MMPI scores in the pathological range, above 70. Since this percentage was the same for the control group and is well within the expectations for such scores based upon the standardization procedures, the conclusion again is that the experimental group parents are not very different in their overall adjustment from parents in general.

It should be noted that the present study has not been concerned with any of the within-group differences. Obviously there can be personality and adjustment differences within the experimental group parents that are theoretically and practically important despite the fact that no important differences between the experimental and control groups were found.

Summary

The Minnesota Multiphasic Personality Inventory (MMPI) was administered to 170 mothers and 157 fathers of children with cleft palates in an attempt to compare the relative psychological adjustment and personality characteristics of these parents to those of a previously studied control group of parents of physically normal children.

While mean differences on five of the MMPI scales were significant, the absolute differences were small in magnitude and the distributions showed considerable overlap.

These results were interpreted as indicating that these two groups were not different in any important way on the MMPI, nor was the performance of either group different from the expected performance of psychiatrically normal persons. The obtained differences were ascribed to sampling problems and to certain socioeconomic level differences between the groups as a function of the techniques used to select them.

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Personality Test Differences in Parents of Children with Cleft Palates

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In an earlier paper Goodstein (2) noted the theoretical and practical importance of knowledge about the personality and adjustment of parents of children with cleft palates. Such knowledge, he pointed out, should be important in understanding the development and adjustment of the child himself and, further, should be important in deciding the potential helpfulness of the parent as an auxiliary therapist. As part of this earlier report, Goodstein compared the personality and adjustment of an experimental group of parents of children with cleft palates with that of a control group of parents of physically normal children by means of the Minnesota Multiphasic Personality Inventory (MMPI). The results with the MMPI were interpreted as revealing no important differences between the two groups of parents, and it was suggested that both groups were not very different in their level of adjustment from unselected parents in general. There are, however, differences in level of adjustment within this group of parents of children with cleft palates as there are within any large group of persons. The purpose of this paper is to report on these within-group personality-test differences and to relate them to other clinical data.

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Procedure

As part of a large-scale, intensive study of the factors related to the adjustment of children with cleft lips and palates, the voluntary participation of 175 families with a child having a cleft lip or palate or both was obtained. A brief summary of the method used to select these parents may be found in the earlier paper (2). While it had been planned to obtain an MMPI profile from each parent, this goal was not realized due to a variety of practical limitations. MMPI profiles were obtained, however, from 170 mothers and 157 fathers in the experimental group and the present report is based upon these cases. Further, for each child with a cleft lip or palate a comprehensive case history had been gathered by an experienced speech pathologist by means of a semistandardized, detailed clinical interview with at least one of the parents, and also through direct observation of the child.

In order to facilitate the comparison of the MMPI profiles with the other quantified data (see below), each of

170 profiles obtained from the mothers was rated along a continuum of personal adjustment. These ratings were obtained by having two clinical psychologists, each with considerable experience in the clinical use of the MMPI, independently rate the profiles, with the ratings forced into a nine-point normal distribution of ratings. The interjudge agreement between these two raters was considered high enough (r=.79) to allow the mean of the two judges' ratings to be used as a single adjustment score. The 157 MMPI profiles obtained from the fathers were rated in the same fashion, had equally good interjudge agreement (r=.75), and were combined in the same fashion. Relationships were then determined between parental adjustment, as defined by these MMPI ratings, and (a) the age of the child, (b) the type of cleft, (c) the social adjustment of the child, and (d) adequacy of overall child handling.

Results

Age of Child. In order partially to evaluate the impact of the entry of a child with a cleft palate into the home, each of the MMPI adjustment ratings for the fathers and mothers was correlated with the child's age (in months). The age of the child was significantly correlated with the adjustment ratings of both the fathers (r=.24, p<.01 for 141 df[1]) and the mothers (r=.27, p<.01 for 153 df). These findings suggest that there is some tendency for the parents of the older child with cleft palate to receive generally somewhat higher ratings, indicating poorer adjustment, than the parents of the younger children. Since it might be argued that the obtained correlations may represent, in part, a relationship between age of parent and MMPI ratings, the ages of the parents of the upper and the lower 15% of the child-age distribution were compared, with the differences being nonsignificant (both ts<.01).

The finding indicating a relationship between age and adjustment is partially substantiated by the comparison of the adjustment ratings of the parents in the upper and lower 15% of the child-age distribution for the mothers and for the fathers. The mean adjustment ratings of the fathers of the 25 oldest children was 5.25 while the mean adjustment ratings of the fathers of the 26 youngest children was 3.66. This difference is statistically significant (t=2.22, p<.05 for 49 df) and indicates that the fathers of the oldest children were rated as being more poorly adjusted than the fathers of the youngest children. The mean adjustment ratings of the mothers of the 23 oldest children was 4.80 while the mean adjustment rating of the mothers of the 26 youngest children was 4.41. This difference is not statistically significant (t=1.1 for 47 df), although the direction of the difference is the same as that found with the fathers.

Type of Cleft. In order to evaluate the relationship between parental adjustment and the type of cleft involved, three separate distributions of ratings were established for the fathers and for the mothers—one for the parents of

[1]The df = N-2. The discrepancy between this figure and the total N reported above is due to the failure to have complete information available on all cases. The discrepant Ns reported in the succeeding analyses are likewise a result of this same problem.

children having a cleft of lip only (N=11), one for the parents of children having cleft of palate only (N=33), and one for parents of children having cleft of both lip and palate (N=109). These distributions of ratings were then compared by means of the medians test; this analysis indicated there were no significant differences in MMPI ratings of adjustment for either the fathers or mothers of the three groups of children ($\chi^2<1$ with 2 *df* in both cases) suggesting that parental adjustment is not related to the type of cleft involved.

Social Adjustment. To examine the relationship between MMPI ratings and the social adjustment of the child, two experienced speech pathologists, after rereading the detailed case histories, especially the summaries, independently rated the social adjustment of the 125 children three years of age and older. (It was felt that social adjustment could not be reliably rated in children any younger than three.) These ratings were made along a nine-point continuum of adjustment, with the ratings forced into a normal distribution in the same fashion as the parental adjustment ratings based upon the MMPI profiles. The interjudge agreement between the two raters was considered high enough (r=.83) to allow the mean of the two judges' ratings to be used as the social adjustment rating.

These social adjustment ratings for each child were then correlated with the MMPI adjustment ratings for each of their parents. The obtained correlation between the mothers' and children's adjustment ratings was .08 (N=109) while the obtained correlation for the fathers' ratings was .05 (N=122). Thus there appears to be no evidence of any relationship between these two sets of ratings.

Adequacy of Handling. On the basis of the case history, two speech pathologists independently rated each parent who participated in the study along a nine-point continuum of adequacy of overall child handling, with the ratings again forced into a normal distribution. The interjudge agreement was again considered sufficiently high (r=.68 for the mothers, N=159; r=.68 for the fathers, N=157) to permit the mean of the two ratings to be used as a single adequacy-of-handling score. Neither the MMPI profiles nor the adjustment ratings based on these profiles were available to these raters.

These parental adequacy-of-handling ratings were then correlated with the MMPI adjustment ratings. The obtained correlation between the mothers' adequacy-of-handling rating and the mothers' MMPI adjustment rating was small and nonsignificant (r=.11 with 155 *df*); the obtained correlation for the two fathers' ratings was likewise small and nonsignificant (r=.07 with 152 *df*). Thus there again appears to be no noteworthy relationship between these two sets of ratings. On the other hand, the parental adequacy-of-handling ratings do show a small but significant correlation with the ratings of the children's social adjustment (r mothers =.39, $p<.01$ for 123 *df*; r fathers =.30, $p<.01$ for 109 *df*).

Extreme Groups. To test further the relationship of the MMPI adjustment ratings to the other ratings, two extreme groups, one well adjusted and the other poorly adjusted, were selected

on the basis of the MMPI ratings with each group comprised of those parents whose mean MMPI adjustment scores were in the upper or lower 15% of the distribution of such ratings (N=18 in each group). The mean social adjustment ratings for the children of the parents in each of these groups was then calculated and the differences between the means tested by means of the *t* test. The differences between the means were small and nonsignificant ($t<1$ in both cases). A similar analysis of the overall adequacy-of-handling ratings for the well and poorly adjusted groups yielded similar negative results; the mean differences were small and nonsignificant ($t<1$ in both cases). Thus it appears that there is no evidence of any relationship between adjustment ratings derived from the MMPI and other ratings, even when only the extreme groups are considered.

It might be argued that these MMPI adjustment ratings, despite their reliability, were invalid and that a study of the actual MMPI scores might show a significant relationship with the case ratings. As one check on such a possibility, the correlations between the Taylor Anxiety Scale (*A*-scale) scores (*5*) and the several ratings were calculated. The decision to use the *A* scale for this analysis was based on the prior demonstrated validity of the *A* scale as an adjustment measure (*1*, *3*), the relative independence of the *A*-scale scores and the MMPI adjustment ratings ($r=.13$ for the mothers, $r=.19$ for the fathers), and the potential clinical efficiency of a single measure. Correlations between the *A*-scale scores and the clinical ratings were consistently small and nonsignificant ($r<.15$ in all cases).

Discussion

The results of the present study suggest that there is no relationship between parental adjustment as inferred from a personality test, and either the rated social adjustment of the child with cleft palate or the rated adequacy of the parents' handling of the child. This is especially noteworthy as it was possible to obtain relatively reliable measures of parental adjustment based on the personality test profile as well as of child adjustment and parental handling. Perhaps the MMPI is not a sufficiently sensitive instrument to be useful in the prediction of the adequacy of the handling of a child with a physical handicap. Hindsight suggests that such a test as the Parent Attitude Research Instrument (*4*) might be more satisfactory for such purposes since it is more directly interpretable in terms of relevant child-rearing attitudes.

One significant finding was that the parents of the older children with cleft palates were rated as more poorly adjusted than the parents of the younger children. One possible interpretation of this finding is that the effects on parental adjustment of having a child with this type of physical handicap in the home are not immediately evidenced but rather develop with time. This finding is not a surprising one since many of the important problems in the management of these children, like the speech difficulty, the need for orthodontics or secondary surgical procedures, are not obvious at birth but become more important as the child grows older.

It may well be that this age factor is obscuring other significant relationships in the data. When the correlation

with age is partialled out, the resultant correlation between the MMPI adjustment ratings and the overall adequacy-of-handling ratings becomes significant for the fathers (r_{par}=.23) but not in the case of the mothers (r_{par}=.13). But these relationships are still quite small and certainly of little practical importance. In general it must be concluded that within the limits of this study parental adjustment ratings based on the MMPI appear to be of little help in understanding the parents of cleft palate children on certain theoretical levels or in making any practical decisions about using these parents in the treatment program.

Summary

The present study was concerned with an attempt to relate the adjustment of parents of cleft palate children, as judged from a personality test, to clinical factors including the age of the child, the type of the cleft, the rated social adjustment of the child, and each parent's adequacy in handling his (her) child. Ratings of the children were made from a detailed case history based on a clinical interview with one or both parents. Ratings of parental personal adjustment were made on the basis of Minnesota Multiphasic Personality Inventory (MMPI) profiles which had been obtained from 170 mothers and 157 fathers of children with cleft palates.

In general it was concluded that ratings of parental adjustment based on the MMPI were of little help in understanding the parents of children with cleft palates on a theoretical level or in making practical decisions about using these parents in the treatment program.

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Relationship of Phonetic Structure to the Intelligibility of Words Simultaneously Recorded at Ear and Lips

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On several occasions, experimenters have reported observation of speech signals picked up in the external auditory canals of speakers. Early work was carried out by Graham and Woodruff[1] in 1932-34 at the Signal Corps Engineering Laboratories, Ft. Monmouth, N. J. In 1952, Hirsh and Benson (*4*) commented upon this phenomenon in a report of research completed for Wright Air Development Center. Two years later, Dolch and Schubert (*3*), while investigating body-conducted sidetone, enumerated several possibilities for the origin of the signal observed in the ear canal. In 1955 Beschle (*1*) attempted isolation of the signal at the ear in order to study its physical characteristics. A year later, Black (*2*) made computations relative to the contributions made by air and bone channels to the signal in and around the ear canal. Also in 1956, a systematic comparison of various kinds of microphones including an ear pickup was begun by Moser and others (*6*).

In a 1955 publication, Oyer (7) reported upon an intelligibility comparison of signals simultaneously recorded at the ear and lips of speakers. The test material for this study consisted of monosyllabic words selected from words used in air traffic control. Vowel, diphthong, and initial-consonant occurrence in the test list approximated the relative frequency of their occur-

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[1]Personal communication to Dr. Moser from Dr. Albert E. Woodruff, Chicago, 1955.

rence in English monosyllables. Six adult male speakers were used and although the material was presented to trained listeners at five S/N ratios (-6, -9, -12, -15, -18 db), the results of only the latter three were reported because of the high degree of intelligibility (nondiscriminating) of all signals at the -6 and -9 db S/N ratios. The investigator concluded that (a) when heard in quiet, speech picked up by a transducer coupled to a custom-fitted ear mold (in the ear of the speaker) is as intelligible as speech recorded simultaneously at the lips of the speaker by a second transducer (same model as at the ear); (b) speech signals from the ear are more intelligible than speech signals from the mouth for all S/N ratios employed, with increasingly large differences at lower ratios; (c) the trend for intelligibility over S/N ratios employed in the test is in the same direction for speech signals of both origins; and (d) decreasing S/N ratio is significantly destructive to the intelligibility of speech picked up at the ear and lips of speakers, and is more destructive to the latter than to the former.

Up to this point the only aspects of ear-origin speech investigated were physical characteristics or intelligibility. It is the purpose of this study to analyze differences in listeners' responses to speech signals picked up in the ear and in front of the lips. Specifically, the following questions were to be answered: are there differences in listeners' responses to ear-origin and lip-origin speech in (a) number of word substitutions, (b) number of omissions, (c) difference between substitutions and omissions, (d) number of word substitutions from outside the original test list, (e) intelligibility of any specific words, (f) word intelligibility as a function of number of sounds in the stimulus words, (g) word intelligibility as a function of specific vowels or diphthongs, and (h) word intelligibility as a function of initial or final consonant. These questions were answered by analyzing in more detail the data from the Oyer (7) experiment in which the word intelligibility of lip-origin and ear-origin speech was compared.

Procedure

The following equipment and procedure were used in the Oyer study:

The test material consisted of 50 monosyllabic words selected from a list of words used in air traffic control, compiled in 1951 by McCormick.[2] The 50-word list was constructed to represent vowel, diphthong, and initial consonant sounds in proportion to the frequency of their occurrence in English monosyllables.

The speakers were six adult males of general American dialect. Each read five randomizations of the 50-word list. Words were read in triplets and preceded by a carrier phrase, such as, 'number one, you will write *base, six, fuel.*' Speakers were instructed to maintain a level inflection on all words.

Two magnetic insert earphones (Dyna-Lab D-69) were employed as

[2]Unpublished Civil Aeronautics Administration (CAA) report of tower count (recording and tabulation of words used in messages from pilot to tower and from tower to pilot) made by M. Y. McCormick, Chief Psychologist, Safety Projects Branch, Medical Division, CAA, as part of CAA study of radiotelephone phraseology used in CAA airport traffic control towers.

TABLE 1. Results of analysis of variance for testing differences among S/N ratios (–12,–15, and –18) and among origins (lip and mouth).

Source	*df*	*ms*	*F*	*P*
Ratios	2	173 501.80		
Origins	1	36 544.69		
Listeners	23	1 841.14		
R x O	2	10 965.05	118.40*	0.01
R x L	46	203.54		
O x L	23	80.91		
R x O x L	46	92.61		
Total	143			

*$F = ms_{RxO}/ms_{RxOxL}$; $F_{.01} = 5.10$.

microphones.[3] Two tape recorders (Ampex 600 and 305) were used. One insert earphone was positioned three centimeters from the lips and the other was coupled to a custom-fitted ear mold in the left ear of each speaker. The

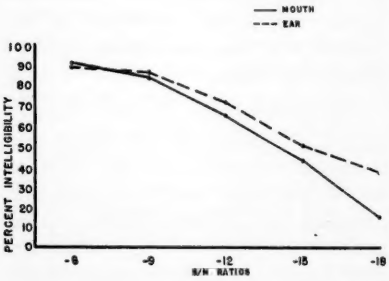

FIGURE 1. Percent intelligibility comparison of mouth and ear signals.

speech signals were thus recorded simultaneously. Tape speed was 7.5 inches per second.

Twelve word lists were randomly transcribed to a training tape. This tape contained 100 stimulus words from each of the six speakers evenly divided with reference to microphone placement.

For the experimental tapes, the speaker lists were randomly transcribed to a master tape. Thus for one listening condition, one ear-recorded and one lip-recorded list from each of the six speakers were represented. No two lists (ear and lip) from the same speaker appeared adjacent to each other. In making the transcription, the level of the last word of each carrier phrase was set between -1 and -2 VU.

Twenty-four American-born university students served as listeners. All listeners were given an audiometric sweep check of hearing. The hearing acuity criterion was set at +15 db or better from 250 through 8000 cps. The listeners were trained on the words for approximately three hours in quiet to an intelligibility criterion of 95%. They were then given an hour and a half of experience in listening in noise.

The test tapes were played back through the same system as the training tape. White noise was mixed with the signal at the output of the attenuator at a level of approximately 74 db. Thereafter, the speech signals were attenuated in order to obtain the desired S/N ratio. The five S/N ratios utilized as test conditions were -6, -9, -12, -15, and -18 db S/N.

As a part of each test session, listeners warmed up to the task by writing down a 36-word list made up of stimulus words from each speaker. Signals picked up at ear and lips were equally represented. A 35-minute test session was followed by a 15-minute rest period. Each listener was required to

[3]The Dyna-Lab D-69 is designed as an earphone and not as a microphone; therefore, it is possible that it would function better at the ear than at the mouth.

TABLE 2. Summary of analysis of simple effects of S/N ratios (differences between ear and mouth origins) and origins (differences among the three S/N ratios).

Effect	*df*	*ms*	*F**	*P*
S/N Ratio –12	1	379.69	4.69	0.06
S/N Ratio –15	1	7 525.02	93.00	0.01
S/N Ratio –18	1	50 570.09	625.00	0.01
Mouth Origin	2	135 370.50	665.08	0.01
Ear Origin	2	49 096.35	241.25	0.01

*Error terms for computing F are from the analysis summarized in Table 1.
$F_{R\ (-12,\ -15,\ or\ -18)} = {}^{ms}R\ (-12,\ -15,\ or\ -18)/{}^{ms}R \times L$, $df = 1$ and 46,
$F_{O\ (-12,\ -15,\ or\ -18)} = {}^{ms}O\ (-12,\ -15,\ or\ -18)/{}^{ms}O \times L$, $df = 2$ and 23.

TABLE 3. Mean values for each origin for each S/N ratio.

*Origin**	*S/N ratios†*		
	–12 db	*–15 db*	*–18 db*
Mouth	199.88	135.13	50.13
Ear	205.50	160.17	150.04

*As indicated by F tests of Table 2, the difference between origins was significant at the 6% level for –12 db S/N ratio and beyond the 1% level for –15 and –18 db S/N ratios.
†Difference necessary for significance at 1% level is $10.60 = t_{.01}(2ms_{RxL}/n)^{1/2}$.

listen for a total of 70 minutes per day. It was assumed that no learning took place during the experiment because of the spacing in testing, the noise conditions, and the randomization of the list.

Results

Findings of the original experiment are shown in Figure 1, Tables 1, 2, and 3. The curves of Figure 1, representing general intelligibility levels of the speech signals for each origin, indicate that the signal picked up at the lips at -6 db S/N is slightly superior in intelligibility to the signal picked up at the ear but that at the four following ratios the ear-recorded signal is more intelligible. As mentioned earlier, statistical analyses were made of data for three of the five S/N ratios, -12, -15, and -18. Table 1 presents the over-all analysis of variance for the ratios-by-origins-by-listeners design for these three ratios. The interaction of ratios-by-origins, which reflects the variation in ear-mouth differences from one S/N level to another, is clearly significant. In view of this variation, the significance of these differences was tested separately at each S/N level, as reported in Table 2. Table 3 presents the values for

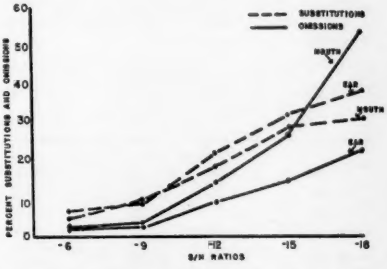

FIGURE 2. Percent substitutions and omissions of words through five signal-to-noise ratios.

TABLE 4. Results of statistical comparisons between substitutions and omissions.

S/N Ratios	*Mean Scores*		*t**
	Substitutions	*Omissions*	
-6 db	16.78	7.16	3.22
-9 db	26.78	9.64	4.71
-12 db	60.22	33.52	5.72
-15 db	90.9	60.16	6.12
-18 db	99.64	109.46	2.60

*$t_{.01}(df = 49) = 2.57$.

origins at each S/N ratio. The analysis of variance was employed to evaluate the data at the three lowest S/N ratios. It was determined that significant differences in favor of the ear existed between intelligibility of signals recorded at ear and lips. At -12 db S/N the difference was significant at the 6% level and at -15 and -18 db at the 1% level.

On the basis of data presented in Figure 2, the first three questions of this study (re substitutions and omissions) can be answered: the percentage of both omissions and substitutions increases as the S/N ratios decrease. From -6 through -15 db S/N the percentage of omissions is less than that of the substitutions for each of the two origins; however, at -18 db S/N the omissions for lips origin far exceed the percentage of substitutions for either origin. Statistical comparison of differences between mean number of substitutions and mean number of omissions, reported in Table 4, shows that significantly more substitutions than omissions occur at -6, -9, -12, and -15 db S/N ratios. At -18 db S/N ratio, significantly more omissions than substitutions occur.

TABLE 5. Statistical comparison of substitutions for the words according to the origins of speech recording.

S/N Ratio	*Mean Scores*		*t**
	Ear	*Lips*	
-6 db	9.64	7.14	1.59
-9 db	12.90	13.90	.48
-12 db	32.10	26.78	2.11
-15 db	46.24	41.64	1.57
-18 db	55.02	44.56	3.56

*$t_{.05}(df = 49) = 1.96$; $t_{.01}(df = 49) = 2.57$.

TABLE 6. Statistical results for comparisons of omissions of words recorded at ear and lips.

S/N Ratio	*Mean Scores*		*t**
	Lips	*Ear*	
-6 db	3.7	3.5	.304
-9 db	5.5	4.1	1.35
-12 db	20.9	13.2	2.65
-15 db	38.6	21.6	4.76
-18 db	77.1	32.5	10.88

*$t_{.05}(df = 49) = 1.96$; $t_{.01}(df = 49) = 2.57$.

Results of the *t* test for related means, applied to differences in substitutions between the mouth-origin recording and the ear-origin recording, are given in Table 5. Differences are not significant at -6, -9, and -15 db S/N but are significant at the 1% level at -18 db S/N and at the 5% level at -12 db S/N, with more substitutions occurring for ear-origin than for mouth-origin recording.

At -6 and -9 db S/N, the differences between mouth and lip recording origins on number of omissions occurring are not significant, as given in Table 6. From -12 through -18 db S/N ratios, differences are significant at the 1% level, with omissions occurring more frequently for lip-origin recording.

TABLE 7. Statistical comparison of substitutions outside the original word list according to the origin of speech recording.

S/N Ratio	*Mean Scores*		*t**
	Ear	*Lips*	
-6 db	.90	.76	.669
-9 db	.44	.74	1.83
-12 db	.30	.46	1.27
-15 db	.62	.40	1.91
-18 db	.50	.20	2.60

*$t_{.05}(df = 49) = 1.96$; $t_{.01}(df = 49) = 2.57$.

In Table 7 the means are presented, according to S/N ratio, for both origins, for the number of word substitutes from outside the original list which were used as responses by the listener. The downward trend from -6 through -12 db S/N is conceivably a commentary on proficiency of training of subjects to listen in noise. Results of *t* tests, also given in Table 7, show that no significant differences exist at ratios -6 through -15 db S/N but that at -18 db S/N the difference is significant at the 1% level.

In Table 8 are given the means for a comparison of the percent intelligibility for words composed of two, three, four, and five sounds, of ear and lip origins, collapsed over five ratios. For lip origin, the intelligibility varies from 58% to 62.5% whereas for ear origin it varies from 66.1% to 66.8%. If increase in number of sounds affected intelligibility in a manner similar to increase in number of syllables, a positive slope in the curves could be expected but this is not the case in this instance. Insofar as difference in intelligibility is related to number of sounds per word, it was found that difference between the responses for speech recorded at ear and lips for three-sound words was significant at the 5% level, in favor of the ear (see Table 8). There were no significant differences between the responses for the two recording origins for one-, two-, four-, and five-sound words. These results are somewhat tenuous in view of the fact that the number of two-sound words was

TABLE 8. Intelligibility comparisons of origins relative to number of sounds in stimulus words.

Number of Sounds	*Mean Scores*		*t**	*df*
	Lips	*Ear*		
2	4.33	7.67	.38	2
3	8.66	11.13	2.24	29
4	4.26	7.00	1.86	14
5	6.50	9.0	8.46	1

*$t_{.05}(df = 2) = 4.30$; $t_{.05}(df = 29) = 2.05$; $t_{.05}(df = 14) = 2.15$; $t_{.05}(df = 1) = 12.70$.

TABLE 9. Statistical results for intelligibility comparisons of words recorded from ear and lip origins in relation to vowel and diphthong sounds contained.

Sound	*Number of Words*	*% Intelligibility*		*t**
		Lips	*Ear*	
[ɪ]	6	56.9	69.4	1.59
[æ]	5	58.2	50.6	3.10
[e]	5	37.9	58.2	2.96
[ɛ]	4	57.6	79.8	3.28
[ʌ]	3	67.5	63.9	1.02
[ɑ]	4	72.2	72.1	.03
[ɔ]	4	72.3	67.5	1.44
[i]	3	37.9	74.3	4.64
[o]	4	64.6	71.0	1.44
[ɑɪ]	4	75.5	75.4	.03
[u]	2	60.3	67.7	.23
[ɝ]	1	76.8	72.6	1.12
[ɑʊ]	2	75.8	61.2	.46
[ɪu]	1	60.9	71.8	.85
[ʊ]	1	71.4	88.1	1.53
[ɔɪ]	1	68.7	54.3	1.52

*$t_{.05}$ $(df = 4) = 2.78$; $t_{.01}$ $(df = 4) = 4.60$.

three; three-sound words, 30; four-sound words, 15; and five-sound words, two.

In Table 9, *t*-test results are presented for differences betwen lip and ear origins on intelligibility with reference to vowel and diphthong sounds contained in the words. Each mean intelligibility measure is a mean for the five S/N ratios. The differences between mean intelligibility scores for the two speech recording origins were significant for the words with the vowels [æ, ɛ, e, i], with words containing vowels [e, ɛ, i] more intelligible from the ear origin and words containing the vowel [æ] more intelligible from the lip origin. Differences between the recording origins were nonsignificant for the remainder of the vowels and diphthongs.

An attempt was made to relate intelligibility of words to the consonant components. No meaningful patterns evolved. Because there were tremendous fluctuations in the values within groups of words with the same initials or terminals, it was decided to make no further analysis. It would appear that a small vocabulary employed with highly trained subjects is more dependent upon vowel than upon consonant components for its intelligibility.

Insofar as confusions among vowels and among diphthongs are concerned, analysis showed that in general the most pronounced confusions are highly similar to those reported by Moser and Dreher (*5*) and by Pickett (*8*): [i/u], [ɪ/u], and [e/o]. For signals recorded at both lips and ear there were [i/u] and [ʌ/ɑ] confusions. For signals recorded at the ear there was a great tendency toward [ɪ/u], [e/i], and [æ/ɑ] confusions.

More confusion occurred for ear-recorded than for lip-recorded speech signals. This is attributable in part to the fact that as listening conditions became more adverse, the listeners tended to omit more of the words recorded at the lips but continued to make attempts to respond to those recorded at the ear.

Summary

A comparative analysis was made of phonetic elements of listener response to recorded speech signals of ear and lip origin for five S/N ratios. It was found that listeners highly trained on 50 words tended to restrict substitute responses to words within the list. Fewer substitutions of words from outside the original list occurred as noise in the listening situation became more destructive. A significantly greater number of omissions occurred for the lip-origin recordings for -12 through -18 db S/N ratios, while the substitutions remained fairly constant throughout the testing. Certain vowels and diphthongs appeared to be related to intelligibility patterns. The most extreme variation in per cent intelligibility occurred for words containing [e], [æ], [i], [ɛ], or [ɪ]. Words containing the [æ] sound were significantly more intelligible when the stimulus was recorded at the lips whereas the opposite was true for the other previously mentioned vowels. There was no apparent relationship between consonant structure and intelligibility of the test words.

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Some Laryngeal Correlates of Vocal Pitch

HARRY HOLLIEN

The present study presents data showing the relationship beween certain measures which may be considered indices of laryngeal size and vocal pitch level, comparisons being made both between the two sexes and among individuals of the same sex.

Heretofore the principal source of information concerning laryngeal dimensions has been the anatomical study of cadaver preparations. Such measurements have been reported by authors such as Gray (*3*), Negus (*5*), Behnke (*1*), Judson and Weaver (*4*), and Boshoff (*2*). Although the differences between male and female measurements listed in these references show significant relationship to the known differences between male and female pitch levels, no information is available to show whether or not the variations within each sex are likewise related to variations of pitch level of voice. Moreover, these data are vulnerable to the criticism that may nearly always be leveled at measurements of cadaver preparations: that they may not adequately represent actual dimensions of living tissue. Other approaches to laryngeal study have consisted primarily of unquantified observation of laryngoscopic films and x-ray photographs. Rarely has an investigator attempted exact measurements of the living larynx under controlled conditions which would make it possible to relate these measurements to observed vocal events.

A technique that has had little application in studying the larynx is that of lateral radiography. Long used in medicine for locating pathology, x-ray procedures provide also a means of investigation having certain advantages over techniques, such as laryngoscopic viewing, that have been more commonly utilized. The advantages of lateral x ray are that it can be used with nearly any subject and, if controls of the subject's position in relation to the x-ray equipment are provided so that appropriate corrections for enlargement can be made, the resulting x-ray films should allow for obtaining accurate measurements on the size of laryngeal structures.

Subjects

The following four groups of subjects were selected so that they differed as radically as possible from one another in pitch level but exhibited a high degree of homogeneity within

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each group with respect to both pitch level and pitch range: group LM, six males with very low pitched voices; group HM, six males with very high pitched voices; group LF, six females with very low pitched voices; and group HF, six females with very high pitched voices. These 24 subjects were selected from a larger sample of 254 volunteers on the basis of the following criteria:

Subjects, ranging in age from 18 to 29 years, were chosen from the student body of the University of Iowa. This population of young adults has the virtues of (a) being old enough to have completed adolescent voice change, and (b) being young enough so that any tissue changes associated with increasing age would not be evident.

Although the effects of formal training in singing upon the laryngeal structures is not known, it is generally accepted that pitch range is increased as a result of voice training. Accordingly, volunteers who had received any appreciable amount of formal vocal training were excluded.

Any volunteer exhibiting speech or voice defects was considered unsuitable since the study was concerned only with normal voices.

Since, under certain of the experimental conditions, subjects would be required to produce various vocal pitches under difficult conditions, those who were not able to sing the scale with ease were eliminated.

It was considered desirable to select pitch groups that would be both homogeneous and as representative as possible of a particular pitch level. Each subject's range of fundamental frequencies (including falsetto) was determined by a standard procedure. All subjects exhibiting extremely wide or extremely narrow pitch ranges were eliminated and only subjects with ranges from 32 to 40 semitones were included. The final six subjects for each group were chosen in order that any individual within a group was as like any other as possible with respect to the lowest note of the pitch range as well as to the extent of the pitch range. The pitch ranges of these 24 subjects may be seen in Figure 1.

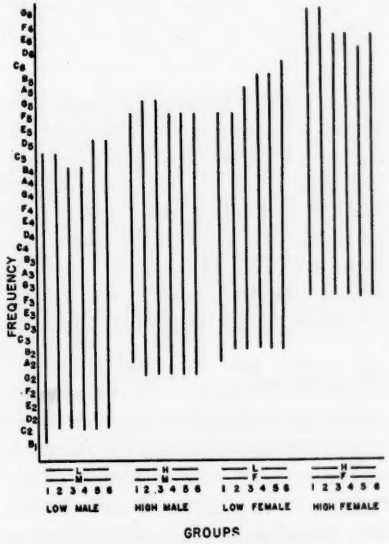

FIGURE 1. Pitch ranges of the 24 subjects.

Procedure

A standard lateral x-ray procedure was used which allowed for very good definition of the outlines of the vocal tract. The equipment used was a standard Picker x-ray unit with a one-millimeter focal spot. Exposure was .20 sec at 200 Ma; x-ray source to

casette distance was 72 in., and a single parspeed intensifying screen was placed in each casette.

In order to avoid subject-to-subject variability, each subject was seated with his or her left shoulder firmly against the x-ray casette. A cork block (or blocks) of dimensions suitable to maintain an exact vertical position of the head, was inserted as spacer(s) between the subject's head and the casette holder. Since the blocks were held in place only by pressure from the subject's head, any movement allowed them to become displaced. Thus, the subject's head and neck were effectively positioned and immobilized. Each subject was positioned with his chin raised until the lower border of the mandible was horizontal. Finally, by means of a centering light beam intrinsic to the x-ray unit, the subject was positioned so that the central ray of the equipment passed directly through the larynx at approximately the point indicated in Figure 2. After the x ray had been taken but while the subject was still in position, the distance from his midsagittal plane to the casette was measured. This distance was used in making standard corrections for enlargement of the structures measured.

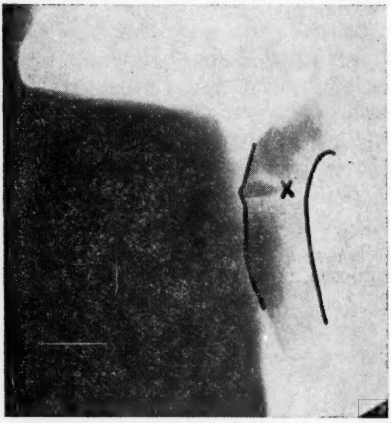

FIGURE 2. An example of a lateral x ray of the vocal tract; 'x' indicates the point at which the central ray passes through the larynx. The laryngeal walls have been partially outlined to provide for better clarity in the photographic reproduction.

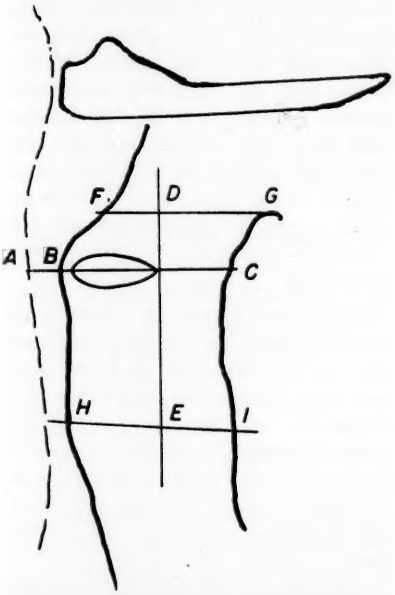

FIGURE 3. Tracing of a lateral x-ray film showing the indices (F-G-I-H) of general laryngeal size and the reference lines established for measuring anteroposterior (A-C and B-C) and vertical (D-E) distances.

Measurements

The size measurements that were chosen will be described by reference to Figure 3, which is a tracing of the borders of the laryngeal tract as seen in a lateral x-ray photograph. First, in order to facilitate their use in measure-

ment, the walls of the laryngeal tract were carefully outlined by following the border of the contrasting shadows. Lines F-H and G-I are these borders. A line bisecting the ventricle longitudinally, line A-C, was then drawn and points B and C, the intersections of this line with the internal anterior surface of the laryngeal tract and with the posterior border of that tract, were located. Line D-E was drawn perpendicular to line A-C at the posterior end of the shadow outlining the ventricle. Finally, lines F-G and H-I were drawn as the best estimate that could be made of the upper and lower boundaries of the laryngeal tract. These lines were drawn as parallels to A-C and were made to pass through landmarks which appeared consistently on the x-ray films. The landmark for the superior line (F-G) was a sharp break in the curve of the posterior boundary of the laryngeal tract. This break was assumed to mark the apices of the arytenoid cartilages. The landmark for the inferior boundary (H-I) was a shadow which was assumed to mark the signet of the cricoid cartilage. H-I was drawn as a tangent to the lower border of this shadow. Because little calcification of the laryngeal cartilages has taken place in these young subjects, the laryngeal cartilages do not cast definite shadows on the x-ray films. However, there was sufficient calcification of the signet of the cricoid so that this landmark was clearly identifiable on the x rays of all but one subject and for these films the position for line H-I was estimated by comparison with other films, use being made of such criteria as the general configuration of the laryngeal tract outline.

From the reference lines described above, four indices of laryngeal size were chosen: two anteroposterior measurements, one vertical measurement, and one area measurement. Since there was no rational basis for assuming that either of the anteroposterior measurements would provide a better index of general laryngeal size than the other, both were included. The four measurements were defined as follows:

Anteroposterior, AP-1 and AP-2. The line A-C was chosen as one index of the anteroposterior extent of the larynx and is hereafter referred to as AP-1; the line B-C was chosen as the other index of the anteroposterior extent of the larynx and is hereafter referred to as AP-2. It is perhaps more closely related to the anteroposterior dimension of the laryngeal tract than is AP-1.

Vertical, D-E. The line D-E was chosen to represent the vertical extent of the larynx.

Area, F-G-I-H. The area measurement F-G-I-H was chosen as an index of the midsaggital cross-sectional size of the internal larynx.

No pretense is made that these indices are absolute measurements of any particular laryngeal dimension. However, they were made from points which could be quite clearly identified on the x-ray films and are believed to be comparable from film to film. Hence, it would seem valid to use them as indices of relative size for investigating the possibility that laryngeal size differs systematically from one pitch group to another.

The reliability with which these measurements could be made was esti-

TABLE 1. Summaries of analyses of variance for testing differences among pitch groups for each of four measures of laryngeal size.

Source	*df*	*ms*	*F**
AP–1 Measures			
Pitch Groups	3	89.3	28.8
Error	20	3.1	
Total	23		
AP–2 Measures			
Pitch Groups	3	105.5	44.0
Error	20	2.4	
Total	23		
Vertical Measures			
Pitch Groups	3	273.9	83.0
Error	20	3.3	
Total	23		
Area Measures			
Pitch Groups	3	212 059.05	83.7
Error	20	2 533.63	
Total	23		

*$F_{.05}$=3.1; $F_{.01}$=4.9.

mated by a standard measure-remeasure procedure and the estimates of measurement errors were: maximum discrepancy, 4.00 mm; mean discrepancy, +0.04 mm; standard deviation of discrepancies, 1.34 mm. Hence, it is apparent that the variations from measurement to measurement were reasonably small and thus provided assurance that the boundary and reference lines could be reliably determined. The final set of measurements which constitute the data actually reported were made from pinholes pricked in the films at points A, B, C, D, and E. The final readings were made to the closest one-half millimeter. All measurements were corrected for enlargement error due to the divergence of the x-ray beam from the source to the film.

Results

Summaries of four analyses of variance for testing differences among group means for each of the four measures are reported in Table 1. All differences among group means are highly significant as indicated by the very large *F*s.

The means for the four measures for each of the four groups are reported, along with the differences necessary for significance at the 5% level, in Table 2. An examination of these means of the corrected measurements indicates, for each measurement, a trend toward smaller laryngeal size as the pitch level of the group becomes higher. All observed differences are

TABLE 2. Means for each of four measures of laryngeal size for each of four groups of voices with critical differences (CD) necessary for significance at the 5% level.

Measures	*Voices*				*CD*
	Low Male	*High Male*	*Low Female*	*High Female*	
AP–1	34.1	30.4	26.6	25.7	2.12
AP–2	24.2	21.2	16.5	15.1	1.86
Vertical	36.7	31.7	26.9	20.8	2.19
Area	715.6	606.0	405.6	301.0	60.62

consistently in the stated direction and all differences between groups are significant except for the two differences between the two female groups for the AP-1 and the AP-2 measurements.

Discussion

The finding of significant laryngeal size differences between males and females is not new and simply confirms the results of previous measurements on cadaver preparations. More meaningful comparisons are possible with the present data since they were obtained from subjects whose vocal pitch characteristics had been ascertained. For example, one can compare high pitched male voices with high pitched female voices. Furthermore, the consistency of these results with previous data lends confidence to the validity of the methods used in the present study for obtaining indices of laryngeal size.

The additional finding of significant size differences between high pitched and low pitched voices within each sex does not necessarily follow from previous knowledge about the larynx, although it seems reasonable and consistent with previous knowledge and was, therefore, not unexpected. With these data it is now possible to make the generalization that within each sex, as well as between the sexes, one of the significant correlates of individual pitch level is over-all laryngeal size.

An additional finding pertains to the relative magnitude of the differences found in the comparison between measurements for the male subjects with high pitched voices and for the female subjects with low pitched voices. Comparison of these means (Table 1) shows that for all the measures the size differences between these two groups are very nearly equal to, and in some cases larger than, the size differences between the two male or the two female groups. This does not seem unusual until Figure 1 is re-examined and the difference observed in pitch levels between the male group with high pitched voices and the female group with low pitched voices. Here it becomes apparent that this pitch difference is much less than that between the other groups. Hence, the size differences between these two groups would seem to be disproportionately large when related to their differences in pitch level. This suggests strongly that when comparisons are made between sexes, there are factors related to laryngeal size which are not completely correlated with the corresponding differences in pitch level.

Finally, it may be pointed out that these data are consistent with a myoelastic theory of phonation in that such an explanation of laryngeal vibration can account for the observed facts of systematic size variation among pitch groups. On the other hand, the neurochronaxic theory does not provide a framework within which these observations can be adequately explained.

Summary

As a result of screening 254 volunteers, four groups of subjects were chosen primarily on the basis of pitch range, age, absence of speech or voice problems, and ability to produce specified vocal tones easily. These groups were composed of: six males with very low voices, six males with very high voices, six females with very low

voices, and six females with very high voices.

A lateral x-ray procedure provided for making four measurements of laryngeal dimensions (two anteroposterior, one vertical, and one area) to establish indices of laryngeal size. Results showed significant trends for laryngeal size to be smaller as pitch level becomes higher. Significant differences in laryngeal size were found both between the sexes and between the pitch groups within sexes. Therefore, it can be concluded that individuals with low pitch levels exhibit generally larger laryngeal structures than do individuals with higher pitch levels.

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Pharyngeal Wall and Palatal Movement in Postoperative Cleft Palates and Normal Palates

ROBERT F. HAGERTY

MILTON J. HILL

Speech problems of individuals with cleft palates can be primarily attributed to an inability to regulate adequately the velopharyngeal orifice. Surgical and prosthetic treatment of cleft palate is mainly directed toward the establishment of an oral chamber in which air pressure can be increased for brief periods when necessary for speech. In their endeavors to learn more about the velopharyngeal complex, investigators have used many methods and tools including anatomical dissection, indirect mirror examination, x ray, and visual inspection through the open mouth or through surgical defects.

Several investigators (*1*, *2*, *5*, *6*, 7, *8*, *9*, and others) have applied radiological techniques to questions concerning velopharyngeal movements during speech in order to study palatal and pharyngeal structures from the lateral aspect. In previous papers (*3*, *4*) the authors presented data on velopharyngeal movement obtained from tracings of lateral laminagraphic skull films of adult normal subjects. The amounts of palatal and pharyngeal wall movement from the rest position to the positions assumed for phonation of the vowel [ɑ] and production of the continuant consonant [s] were measured and reported.

In the present paper are reported the results of an investigation of palate and posterior pharyngeal wall mobility in a group of young subjects with cleft palates and a group with normal palates. The groups were equated as to age, sex, and race.

Procedures and Equipment

Equipment and procedures employed were the same as those used in the earlier study of adult normals. Lateral laminagraphic skull films were made of 50 white postoperative cleft palate subjects ranging in age from seven to 25 years and 50 white normal subjects ranging in age from seven to 22 years. The average age of the cleft palate

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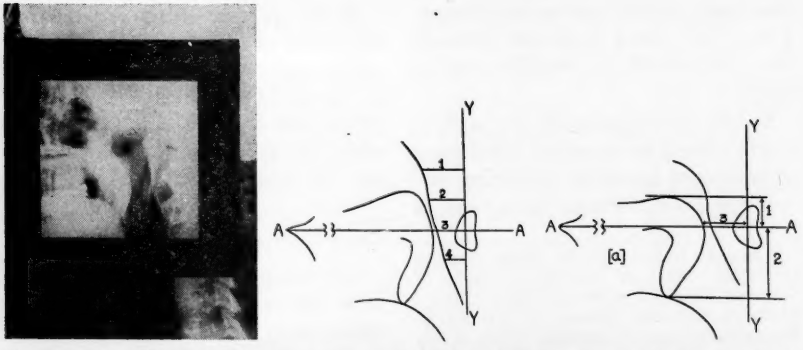
group was 13.2 years and of the normal group, 13.3 years. No groupings were made on the basis of operative procedure or original type of cleft. Included in the cleft palate group were, using Veau's classifications, 14 Types I and II (I, cleft of the soft palate only; and II, cleft involving hard palate but not anterior to incisive foramen), 28 Type III (complete unilateral cleft extending from the uvula through the alveolus on one side), and eight Type IV (complete bilateral cleft extending from the uvula through the alveolus on both sides of the premaxilla).

The laminagraphs were taken under three conditions: (a) with the soft structures at rest; (b) during phonation of the vowel [ɑ]; and (c) during production of the continuant consonant [s] or while blowing a toy horn. The subjects were carefully prepared for maintaining the desired conditions during the time the laminagraphs were being taken; trained personnel was present to listen and judge whether the sounds produced were the phonemes which were desired. No judgements of voice quality were made.

The duality of the third condition was necessary because many of the cleft palate subjects were unable to produce the [s] sound and because an undesired selective factor would have been introduced if they had been eliminated from this part of the study. Comparison of measurements of x rays of normal subjects while producing [s] and while blowing a toy horn demonstrated no appreciable difference in the velopharyngeal movements necessary to perform those two tasks. In the third condition, therefore, the cleft palate subjects who were unable to produce [s] correctly were required to blow the toy horn.

Tracings were made of the portion



FIGURES 1, 2, 3. Figure 1, left, conventional radiographic skull film. Square depicts area from which tracings shown in Figures 2, 3, and 4 were made. Figure 2, center, line drawing of laminagram of subject phonating [ɑ]. Drawing shows the main reference line, A-A, drawn from anterior nasal spine to midpoint of the tubercle of the atlas; the perpendicular, Y-Y, erected at the midpoint of the tubercle; and the levels 1, 2, 3, and 4 at which the distance from Y-Y to the posterior pharyngeal wall was measured. Figure 3, right, line drawing of laminagram of subject phonating [ɑ]. Measurements recorded to determine palatal movement were: 1, velar height above A-A; 2, distance of tip of velum below A-A; 3, distance from posterior surface of velum at selected level (see text) to Y-Y along line parallel to A-A.

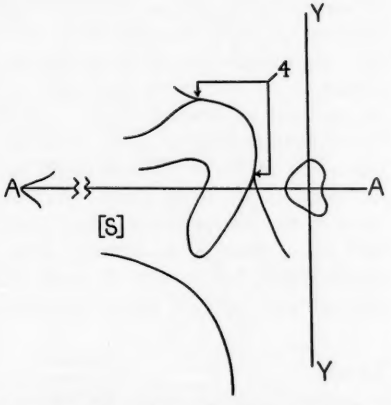


FIGURE 4. Line drawing of laminagram of subject producing [s]. Drawing shows (4) how measurement of extent of velopharyngeal contact was obtained.

of the films within the inset in Figure 1.[1] The main reference line, A-A in Figure 2, was drawn from the anterior nasal spine or, in those subjects having no nasal spine, from a selected point approximating the anterior nasal spine to the midpoint of the anterior tubercle of the atlas. At the midpoint of the tubercle a perpendicular to line A-A, designated Y-Y, was erected.

Movement of the posterior pharyngeal wall was determined by measuring in each of the three subject conditions (rest, [ɑ], [s]) the distance from the perpendicular Y-Y to the surface of the pharyngeal wall at four arbitrarily selected levels along or parallel to line A-A: level 1, 2 cm above A-A; level 2, 1 cm above A-A; level 3, along A-A from the midpoint of the tubercle; and level 4, 1 cm below A-A (Figure 2).

[1]Figures 1, 2, and 3 were presented in an earlier study (*J. Speech Hearing Res.*, 1, 1958, 326) but are repeated here for the convenience of the reader.

To evaluate further the amount of movement, measurement was made by use of a rolling disc planimeter of the area bounded by Y-Y, the posterior pharyngeal wall, and the lines marking levels 1 and 4.

Palatal movement was determined by measuring the following in each of the three subject conditions: the maximal distance of the velum above line A-A; the maximal distance of the velum below line A-A; the distance from the posterior margin of the velum to line

TABLE 1. Mean differences, in millimeters, between rest and (ɑ) positions of posterior pharyngeal wall in normal palate and postoperative cleft palate groups with measurements made at selected levels along lines parallel to line from anterior nasal spine to midpoint of tubercle of atlas; also differences, in square centimeters, of area bounded by posterior pharyngeal wall, line Y-Y, and lines of levels 1 and 4 (see Figure 2).

Measurement		*Normals*	*Clefts*	*t**
Level 1	*mean*	− .20	1.03	2.77**
	SD	1.79	2.12	
	t†	.64	3.29**	
Level 2	*mean*	.20	.52	.56
	SD	3.55	1.97	
	t	.40	1.87	
Level 3	*mean*	.63	.54	.21
	SD	2.44	1.78	
	t	1.83	2.14††	
Level 4	*mean*	.32	− .11	1.38
	SD	1.40	1.98	
	t	1.61	.45	
Area	*mean*	.16	.16	0
	SD	.43	.42	
	t	2.61††	2.63††	

*For testing difference between means of groups.
†For testing difference of group mean from zero.
**Significant at the 1% level.
††Significant at the 5% level.

Y-Y at a selected level (see 1, 2, 3, Figure 3); and the extent of velar contact with the posterior pharyngeal wall, that is, the distance from the most superior point to the most inferior point of contact as measured along the line of contact using a map measuring device (see 4, Figure 4).

The distance from the posterior margin of the velum to line Y-Y was measured at the level of the point of nearest approximation of the velum to the posterior pharyngeal wall during phonation of [ɑ]. The measurement was along a line parallel to A-A. In those cases where the opposing surfaces were equidistant over an extent of several millimeters, a midpoint was selected. Utilizing this same level, similar measurements of the posterior excursion of the soft palate were made in the rest and [s] tracings. This method was devised in order that the posterior movement of the soft palate might be measured at its most active level in relation to the posterior pharyngeal wall rather than at an arbitrary level which might fall outside the area of greatest usefulness of palatal activity.

TABLE 2. Mean differences, in millimeters, between rest and [s] positions of posterior pharyngeal wall in normal palate and postoperative cleft palate groups with measurements made at selected levels along lines parallel to line from anterior nasal spine to midpoint of tubercle of atlas; also differences, in square centimeters, of area bounded by posterior pharyngeal wall, line Y-Y, and lines of levels 1 and 4 (see Figure 2).

Measurement		*Normals*	*Clefts*	*t*
Level 1	*mean*	.94	1.53	1.08
	SD	2.60	2.05	
	t	2.00	5.10*	
Level 2	*mean*	− .28	1.33	2.78*
	SD	3.38	2.30	
	t	.58	4.08*	
Level 3	*mean*	.73	2.12	2.45†
	SD	1.77	3.59	
	t	2.91*	4.17*	
Level 4	*mean*	.06	.53	1.18
	SD	1.39	2.46	
	t	.30	1.52	
Area	*mean*	.21	.42	1.89
	SD	.50	.62	
	t	2.95*	4.62*	

*Significant at the 1% level.
†Significant at the 5% level.

Results

Pharyngeal Wall Movement. In Tables 1 and 2 are the means, standard deviations, and results of *t* tests of the amount of movement from rest to [ɑ] and rest to [s] in each group, and results of *t* tests of the differences between the groups. In each instance of a significant difference between the groups, the difference is in the direc-

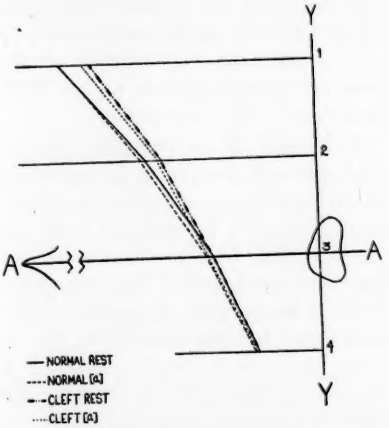


FIGURE 5. Schematic diagram demonstrating the differences between the mean pharyngeal wall profiles of the normal group and postoperative cleft palate group at rest and phonating [ɑ].

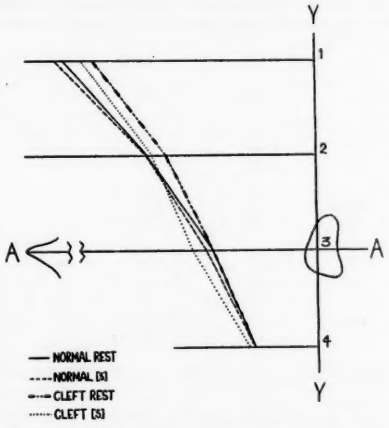


FIGURE 6. Schematic diagram demonstrating the differences between the mean pharyngeal wall profiles of the normal group and postoperative cleft palate group at rest and producing [s].

tion of greater movement in the cleft palate population. It should be mentioned here, however, that among the 50 cleft palate subjects there was only one instance of velopharyngeal contact (that is, complete closure as viewed from the lateral aspect) during phonation of [ɑ], and only 14 during production of [s]. Among the normal subjects there were 33 closures for phonation of [ɑ] and 50 (all) during production of [s]. Figures 5 and 6 demonstrate diagrammatically the differences between the pharyngeal wall profiles of the normal and cleft palate groups at rest and during production of [ɑ] and [s]. The differences between the pharyngeal wall profiles in the rest position were of statistical significance only at level 1.

It is a question whether any difference would be demonstrated between normals and clefts if the normal palates were not indenting the posterior pharyngeal wall, or if there were palatopharyngeal contact in the clefts which perhaps would restrain the pharyngeal wall movement and result in slightly less forward excursion. The same question arises in consideration of the number of instances in which Passavant's cushion was seen in each group. Among the normals, four cushions were seen during phonation of [ɑ] and three during production of

TABLE 3. Mean differences, in millimeters, between rest and [ɑ] positions of soft palate in normal palate and postoperative cleft palate groups. A-A is line drawn from anterior nasal spine to midpoint of tubercle of atlas; Y-Y is perpendicular to A-A at midpoint of tubercle.

Measurement		*Normals*	*Clefts*	*t*
Increase in Velar Distance above A-A	*mean*	3.96	2.44	2.49*
	SD	2.38	3.49	
Decrease in Velar Distance below A-A	*mean*	6.80	5.63	1.36
	SD	4.79	3.70	
Decrease in Distance Y-Y to Velum	*mean*	19.63	10.03	7.90†
	SD	5.42	6.57	
Extent of Velar Contact with Pharyngeal Wall	*mean*	17.03 (N=33)	10.00 (N=1)	

*Significant at the 5% level.
†Significant at the 1% level.

TABLE 4. Mean differences, in millimeters, between rest and [s] positions of soft palate in normal palate and postoperative cleft palate groups. A-A is line drawn from anterior nasal spine to midpoint of tubercle of atlas; Y-Y is perpendicular to A-A at midpoint of tubercle.

Measurement		*Normals*	*Clefts*	*t*
Increase in Velar Distance above A-A	*mean*	6.29	2.36	7.16*
	SD	5.45	3.13	
Decrease in Velar Distance below A-A	*mean*	8.67	5.34	3.69*
	SD	4.29	4.72	
Decrease in Distance Y-Y to Velum	*mean*	20.69	7.98	9.14*
	SD	5.30	8.21	
Extent of Velar Contact with Pharyngeal Wall	*mean*	21.18 (N=50)	11.29 (N=17)	

*Significant at the 1% level.

[s]. Seven clearly defined cushions were seen in the postoperative clefts phonating [ɑ], and 13 in that group during production of [s]. Probably the most important observation the data allow concerning this somewhat controversial phenomenon is that since it is seen in so few instances it is extremely unlikely that Passavant's cushion is necessary to normal speech production for most persons.

For both clefts and normals the actual amount of forward excursion of the posterior pharyngeal wall is very small and its contribution to speech is probably insignificant.

Palatal Movement. Comparison of the movement of the postoperative cleft palates and the normals reveals a distinct limitation of activity in the postoperative palates in all important functions. Their mean upward movement above line A-A from rest to [ɑ] was less than two-thirds that of normals, and from rest to [s] only about one-third. Only one of the post-

TABLE 5. Mean differences, in millimeters, between [ɑ] and [s] positions of soft palate in normal palate and postoperative cleft palate groups. A-A is line drawn from anterior nasal spine to midpoint of tubercle of atlas; Y-Y is perpendicular to A-A at midpoint of tubercle.

Measurement		*Normals*	*Clefts*	*t*
Increase in Velar Distance above A-A	*mean*	2.36	− .08	17.85*
	SD	1.91	2.52	
Decrease in Velar Distance below A-A	*mean*	1.87	− .29	2.90*
	SD	2.80	4.45	
Decrease in Distance Y-Y to Velum	*mean*	1.13	−2.05	3.69*
	SD	1.78	5.64	

*Significant at the 1% level. It may be observed that the variances for the two groups evidence at least moderate heterogeneity. However, the sizes of the *t* values are such that it is reasonable to assume that they cannot be attributed to the heterogeneity alone.

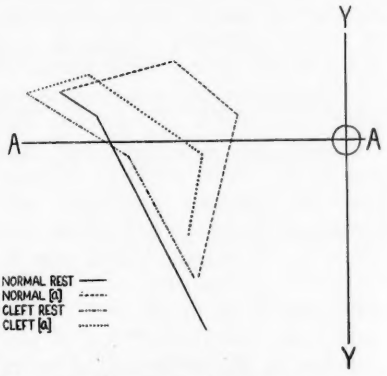


FIGURE 7. Diagram showing mean group profiles of posterosuperior surfaces of normal and postoperative cleft palates at rest and phonating [a]. Difference between rest and [a] contours represents amount of movement.

operative palates contacted the pharyngeal wall during phonation of [a], and 17 during production of [s]. In contrast, 33 normal palates contacted the pharyngeal wall during phonation of [a], and 50 (all) during production of [s]. Mean posterior movement of the postoperative palates was one-half that of normals for [a] and only one-third that of normals for [s].

Tables 3, 4, and 5 show the mean amounts of palatal movement from rest to [a], rest to [s], and [a] to [s] for the two groups, the standard deviations from the means, and results of *t* tests for evaluating the differences between the groups. It will be seen that the differences between groups are significant in all but one instance: upward movement of the tip of the velum from rest to [a]. Figures 7, 8, and 9 demonstrate diagrammatically the manner and extent of posterosuperior movement from rest to [a], rest to [s], and [a] to [s], respectively, in the normal and postoperative palates studied. The differences between the groups are clearly evident in these figures. It will be noticed that in both

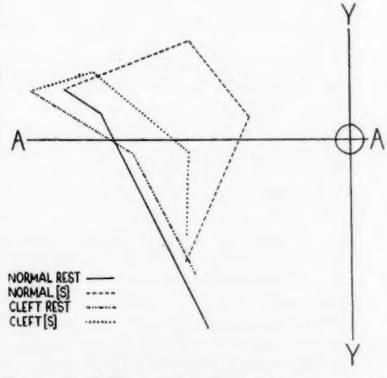


FIGURE 8. Diagram showing mean group profiles of posterosuperior surfaces of normal and postoperative cleft palates at rest and producing [s]. Difference between rest and [s] contours represents amount of movement.

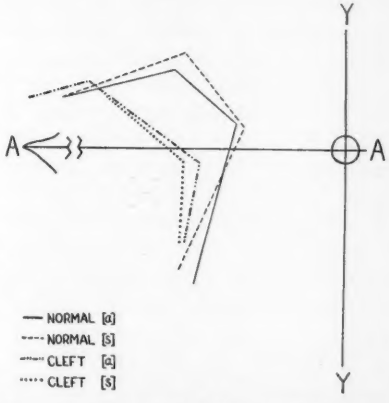


FIGURE 9. Diagram showing mean group profiles of posterosuperior surfaces of normal and postoperative cleft palates phonating [a] and producing [s]. From the [a] position the normal palates move toward the pharyngeal wall while the postoperative palates move away from it.

groups the high point of the palate above A-A moves posteriorly during production of the sounds studied, and the pendant uvular tip curls to point anteriorly.

In routine clinical x-ray studies it has been observed by the authors that postoperative cleft palates frequently show a wider velopharyngeal aperture, or, in other words, less excursion from the rest position, when the patient is attempting to produce [s] than while phonating [ɑ]. It would seem that the patient gives up, or makes only a half-hearted attempt at good closure for [s]. This clinical observation appears to be corroborated by the data in Table 5 showing a significant difference between the amounts of movement from [ɑ] to [s] as measured from Y-Y to the posterior surface of the velum.

The fact that 17 of the postoperative cleft palates did make velopharyngeal contact is probably partially attributable to the greater incidence (13 to 3) of Passavant's bar among the cleft palate group. Nine of the 17 contacted the pharyngeal wall only on the apex of the forward bulging Passavant's bar.

Summary

Palatal and pharyngeal movement in two matched groups, 50 subjects with normal palates and 50 subjects with postoperative cleft palates, was studied and compared by measurements of tracings from laminagrams of the palatopharyngeal area made while subjects were at rest, phonating [ɑ], and producing [s].

The results indicate a tendency for more forward movement of the pharyngeal wall in the postoperative cleft group than in the normal group. A distinct limitation of activity was noted in the postoperative palates in all important functions: upward movement from rest to [ɑ] was less than two-thirds that of normals, and from rest to [s] about one-third. Contact with the posterior pharyngeal wall during production of [s] was seen in all of the 50 normals but in only 17 of the 50 postoperative subjects. Posterior movement of the postoperative cleft palates was one-half that of normals for [ɑ] and only one-third that of normals for [s].

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Relationships between Selected Auditory Perceptual Factors and Articulation Ability

CHARLES V. MANGE

The process of speech production has been discussed in some detail by Fairbanks (*3*). He compares this process to that of a servosystem and describes the general functions of the components involved in producing speech. One of these components, auditory monitoring, is considered to be of great importance by Van Riper (*20*), Ainsworth (*1*), Davis (*2*), and many others as manifested by their emphasis on the efficacy of ear training techniques in speech therapy. This area of audition forms the general locus of the present study.

Audition normally serves as the principal controlling unit in the speech servosystem, the motor aspect being subject, in large part, to the command of audition. In cases of auditory deficiency, defective articulation may arise either from a defective model which guides the output or from a failure of the mechanism which compares the output with the intended or desired production. Not of concern here is the case where the model and the comparative mechanism may be adequate but where the motor mechanisms are inadequate, for example, in certain forms of cerebral palsy. In either case it would be reasonable to assume that the defect originally arose from a failure of the comparative mechanism from which the original auditory image or model had to be derived. Substandard function of some component of the speech servomechanism would then appear to be a possible cause of many functional articulatory disorders.

This investigation was designed to examine the hypothesis that one of the principal causative factors in certain functional articulatory defects is the presence of some auditory deficiency or immaturity which permits continued defective articulation beyond the normal developmental period.

Previous studies of auditory abilities and functional articulation deficiency have been concerned almost wholly with auditory memory span and phonetic discrimination. Although a degree of auditory memory span ability is undoubtedly necessary for speech and articulation adequacy, it is likely that additional ability beyond this basic degree bears little or no relationship to articulatory ability. The results of phonetic discrimination studies, however,

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suggest that some relationship exists between discrimination and articulation ability despite contradictory reports (*4*, *8*, *10*, *11*, *16*, *19*). In addition, Spriestersbach and Curtis (*17*) have indicated that the results of the Roe and Milisen (*13*) and Sayler (*14*) studies suggest a maturing sequence of articulation ability which is related to a progression from lack of phoneme awareness to phoneme recognition to successively finer phoneme discriminations. The maturing sequence to which they refer may be manifested in a progression of errors from omissions to substitutions to distortions. They also suggest some relationship between auditory perceptual abilities and the degree of articulation normalcy or defectiveness.

At least two factor-analysis studies of auditory perceptual abilities have been reported (*5*, *6*). Inspection of the reported abilities and the research in the etiology of functional articulatory defects indicated five possible auditory perceptual abilities which have not been adequately investigated in relation to functional articulation problems. These were discrimination of pitch, discrimination of loudness, discrimination of quality (timbre), rate of auditory perception (flutter and fusion), and phonetic word synthesis (meaningful interpretation of auditory stimuli under conditions of distortion).

Procedure

The tests selected to measure these abilities included the Seashore measures of Pitch, Loudness, and Timbre (Series A-1939 revision); a test of auditory flutter fusion rate; and a test of word synthesis.

The Seashore tests require discriminations such as *higher* or *lower*, *stronger* or *weaker*, and *same* or *different* when pairs of auditory stimuli are presented. The tests are scored by counting the number of correct discriminations.

The auditory flutter fusion test employed in this experiment measured the rate at which rapidly presented discrete bursts of white noise fused perceptually into a continuous sound. The test was constructed by interrupting a continuous white noise with an electronic switch. Interruption frequencies from 30 to 130 per second were used at intervals of 10 interruptions per second. Interruption frequencies were randomly presented and subjects judged whether they heard one long sound or many short sounds. The test was scored by counting the number of presentations judged to be composed of many short sounds; thus, a higher numerical score indicated that more discontinuous stimuli were observed and, consequently, that fusion occurred at a higher interruption rate.

The auditory synthesis test was constructed by making tape recordings of a number of individual continuant speech sounds and then splicing these recordings together to form series of three phonemes; these series contained the sounds and sequence required to produce a version of familiar words. Distortion resulted from a lack of transition from phoneme to phoneme and from use of a uniform intensity and pitch level for all phonemes. The items used in this test were presented at a duration which approximated the duration required for a single utterance of the parent word and at two, four, six, and eight times this duration. It was

assumed that the ability to perform well on this test required an auditory-cortical function of a higher level than that required for auditory-peripheral reception. Scoring of the test consisted of a count of the number of words accurately recognized.

Templin's (*18*) articulation screening test was administered to all subjects to assess articulatory ability. This test required the subject to produce 40 words containing 21 different consonantal phonemes for which articulation was judged. Each subject was required to repeat the 40 words. As the words were produced, articulatory errors were noted on a master subject sheet. Validity and reliability of the judgments of articulation were judged to be adequate following appropriate statistical and subjective analysis.

Subjects. A group of 35 children with functional misarticulation of [r] and a group of 35 matched normal-speaking children served as the experimental and control groups. It was required that each of the children in the experimental group exhibit functional misarticulations involving the [r], but not the [s] sound. In this way the experimental group was similar to one of the experimental groups in a previous study (*10*) in which subjects who misarticulated [r] showed relatively poor phonetic discrimination ability. Many of these subjects exhibited errors involving phonemes in addition to the [r].

The subjects in the experimental group were all assumed to be of the commonly accepted functional type since examination of school records, records of the referring screening therapist, and an examination by the experimenter revealed no organic or structural conditions which might lead to an articulatory problem. None of the children selected had received previous speech therapy.

Four factors were considered in matching the children having functional misarticulations with those who were normal speaking. These were (a) classroom, (b) intelligence, (c) age, and (d) sex. It was believed that matching on the basis of classroom was important for the test of auditory synthesis. It was assumed that all teachers do not use a phonic approach to teaching of the language arts and that matched subjects from different classrooms might not have had equal training in phonics. Intraclassroom matching was an attempt to equate the groups on this training.

The relationships between intelligence and the scores obtained on tests in this study were expected to be low; these relationships, however, had not been determined previously for some of the tests. Consequently, it seemed advisable to control the influence of this factor. Subjects were matched as closely as possible on intelligence within the other limitations of classroom and sex. The mean intelligence quotient for the control group equalled 99.46 while that for the experimental group equalled 100.09. Scores from several different intelligence tests, equated as closely as possible by appropriate statistical procedures, were used in matching the subjects.

Subjects were matched as closely as possible on age since the study of phonetic discrimination by Mange (*10*) and the Seashore norms for several grade levels (*15*) suggest a positive

TABLE 1. Intercorrelations among age, mental age, and experimental test scores for two groups: Control (C), children with normal speech (N = 35); and Experimental (E), children with misarticulated [r] (N = 35).

Variable	*Group*	*Articulation Errors*	*Fusion*	*Timbre*	*Loudness*	*Pitch*	*Synthesis*	*Mental Age*
Age	C		−.11	.09	.02	.04	.40*	.44†
	E	.09	.21	−.08	.26	−.12	−.15	.44†
Mental age	C		.68†	.19	−.35*	.26	.21	
	E	−.25	.45†	.62†	.15	.24	.39*	
Synthesis	C		−.20	.12	.04	.02		
	E	−.58†	.26	.10	−.06	.32		
Pitch	C		.17	.31	.39*			
	E	−.30	.08	.24	.16			
Loudness	C		−.04	.12				
	E	−.07	−.13	.07				
Timbre	C		−.08					
	E	−.01	.01					
Fusion	C							
	E	−.12						

* Significant at the 5% level.
† Significant at the 1% level.

relationship between age and certain auditory abilities. Control subjects ranged in age from 9 years, 2 months to 12 years, 4 months with a median age of 10 years, 8 months; experimental subjects ranged from 9 years, 4 months, to 12 years, 8 months, with a median age of 10 years, 6 months. Individual subjects were matched as closely as possible on age. The majority of subject-pairs were within three months of identical chronological age.

Matching on the basis of sex was desirable since sex differences on phonetic discrimination tests have been reported by other investigators (7, 9). Subjects included 23 matched pairs of boys and 12 matched pairs of girls.

All subjects were given a sweep test of hearing at 15 db to rule out the possibility of hearing acuity defects. Subjects were required to respond to all octave frequencies from 250 through 4000 cycles in both ears. These requirements were adopted since a number of the tests utilized in the study depended upon adequate hearing of specific frequencies and the synthesis test required accurate perception of many speech sounds with frequency components throughout this range.

Each subject also was required to retain and reproduce a series of three phonemes with a duration of approximately two seconds per phoneme to insure that he would be able to remember the phonemes of the synthesis test long enough to permit synthesis into words.

Test Presentation. The order of test

presentation was independently randomized for each subject.[1] The two subjects of a pair were tested together in groups of two pairs or one. All auditory tests were presented by Magnecord PT6-A recorder and PT6-J amplifier through Permoflux PDR-1 earphones. Brief rest periods were provided after each test and a five-minute rest was given midway through the testing. Administration of all the tests consumed approximately 65 minutes for any one group.

Results

Intertest Relationships. For the control and the experimental groups separately all intercorrelations were obtained (Table 1) among the following measures: five experimental tests (synthesis, pitch, loudness, timbre, fusion), articulation, mental age, and chronological age. Most of the interrelationships were low. Usually they were of about the same magnitude and direction for both normal and articulation-defective groups. In those few cases which were of different magnitude or sign, the differences may be important but it was not within the scope of this study to investigate them further. The low interrelationships among scores on the auditory tests suggest that the tests measured separate auditory abilities.

Relationships between Auditory Measures and Articulation Errors. The fact that several of the auditory and matching measures had low to moderate correlations with articulation errors may be somewhat misleading. It is quite possible that a single factor underlies all of the variables and accounts for their relationships to the articulation measure. In order to clarify the relationships of the various auditory and matching variables to articulation errors, a multiple regression analysis was performed on the data for the experimental group. The articulation score was used as the dependent measure, the auditory test scores and matching ages as the independent measures. This analysis was not udertaken to ascertain how well the articulation score might be predicted. Rather, its purpose was to assess the degree to which each auditory test represented independent, unique, and possibly causal factors contributing to articulation defects.

TABLE 2. Regression data for auditory tests and matching variables for articulation errors.

Factor	*Pearson r*	*β*	*βr*
Synthesis	−.58	−.43	.25
Mental Age	−.25	−.36	.09
Timbre	−.01	.31	.00
Chron. Age	.09	.19	.02
Pitch	−.30	−.12	.03
Fusion	−.12	.11	−.01
Loudness	−.07	−.07	.00

The presence of such unique factors is reflected for each variable by the product of its multiple regression weight and its first-order correlation with articulation errors. These products are presented in Table 2. From them it may be seen that the synthesis test provides the best measure of factors re-

[1]Randomization of test order has the effect of depressing the relationships among tests when learning or fatigue are of substantial importance. In this study, however, a random distribution of fatigue and learning effects among the various tests seemed preferable to a concentration in a single test. This concentration would have occurred if a single order had been used for all subjects.

TABLE 3. Experimental test means and standard deviations and *t*-test results for differences between two groups: Control (C), children with normal speech; and Experimental (E), children with misarticulated [r].

Test	*Group*	*Mean*	*SD*	*t*
Pitch	C	32.69	6.55	3.56*
	E	28.69	5.46	
Loudness	C	37.17	7.91	1.11
	E	35.46	7.34	
Timbre	C	36.31	5.39	.71
	E	35.40	5.63	
Synthesis	C	23.66	9.20	.62
	E	22.29	11.19	
Fusion	C	15.20	5.50	.96
	E	16.31	5.67	

*Significant at the 1% level.

lated to misarticulation of [r]. Mental age—that is, general intellectual maturation—possibly accounts to a minor extent for differences in articulation errors. All other measures are of negligible importance. The partial correlation of the synthesis test with articulation errors (all other factors held constant) was –.37, a value significant at the 5% level.

It should be noted that the significant correlation of the synthesis test to articulation errors does not constitute proof of a causal relationship between these variables. The data, however, are consistent with the hypothesis of causality.

Intergroup Test Scores. Mean scores for the normal and articulation-defective groups on the three Seashore measures and the synthesis and fusion tests are shown in Table 3. Intergroup differences between means were compared through the use of *t* tests. The difference between group means for pitch discrimination was significant at the 1% level ($t = 3.56$). Differences for loudness discrimination ($t = 1.11$), timbre discrimination ($t = .71$), synthesis ability ($t = .62$), and fusion score ($t = .96$) were not significant at the 5% level. In all cases the higher mean score was obtained by normal subjects. These results are not necessarily in conflict with the results of the multiple correlation products which showed that pitch discrimination made no important contribution to number of articulation errors and that synthesis made the greatest contribution. The *t* ratios were used to evaluate differences between groups while the multiple correlation products were used to evaluate the influence of factors within the experimental group. Thus, pitch discrimination appears to be related to normalcy or defectiveness of articulation but not to number of articulatory errors. Synthesis ability appeared to be related to number of errors but not to normalcy or defectiveness.

It may be postulated that there is no true dichotomy between normal and defective articulation; it is more likely that there are many degrees of normalcy and defectiveness and that the categories overlap. Thus, it would seem that a factor which is related to normalcy and defectiveness must also be related to the extent of defectiveness. The findings of this study do not rule out this possibility. For example, there are differences between mean scores of the control and experimental groups on synthesis ability, although nonsignificant, and the obtained relationship between pitch and synthesis scores (*r*

= .31) approaches statistical significance. Hence, some of the abilities required for pitch discrimination also may be a part of synthesis ability. These common abilities underlying both pitch discrimination and synthesis, if there are such, might then show a greater relationship to normalcy and defectiveness and to extent of defectiveness than synthesis or pitch alone. Further analysis of the abilities and capacities common to synthesis ability and pitch discrimination thus is suggested.

Summary

The relationships between articulation ability and five auditory abilities were investigated in this study. Auditory tests included the Seashore measures of Pitch, Loudness, and Timbre; a test of auditory flutter fusion rate; and a test of word synthesis. Comparison of mean scores was made between a control group of normal-speaking children and an experimental group of children with functional misarticulation of [r]. Results included the following:

There was a significant, but low, partial correlation between phonetic word-synthesis ability and number of articulation errors; there were no significant relationships between other auditory abilities tested and number of articulation errors.

The control group achieved significantly higher scores than the experimental group in discrimination of pitch. There were no significant differences between mean scores of control and experimental groups on other auditory abilities tested; in all cases the control group achieved numerically higher mean scores.

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Motivating Instructions and Language Performance of Dysphasic Subjects

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This study was designed to investigate the hypothesis that listener reactions influence the language performance of dysphasic subjects. The reactions chosen for investigation were those which would be communicated explicitly or implicitly to the dysphasic individual by persons coming into contact with him.

Increasing importance is being given currently to the idea that the language deficit of dysphasic subjects cannot be attributed solely to the physiological results of the brain injury. Various writers have stressed the fact that part of the symptomatology attributed to the brain damage in dysphasic patients may be a function of anxiety. The presence of anxiety in brain-damaged individuals is substantiated by Piotrowski (*21*), using the Rorschach approach. Linn and Stein (*17*) and Linn (*16*), exploring the reactions of a small number of dysphasic patients to intravenous administration of sodium amytal, found an immediate improvement in language performance following injection. They postulated that this improvement was due to the removal of the inhibiting effects of anxiety. Billow (*5*) using sodium amytal obtained similar results but found, that with repeated administration, dysphasic subjects developed a tolerance to the drug and showed no change in language performance. On the other hand, Bergman and Green (*4*) found no improvement in language performance following single or repeated intravenous administration of sodium amytal. Eisenson (*29*, pp. 450-467) reports on the basis of his clinical experience that dysphasic disturbances following brain damage are more likely to be found in persons of above average intelligence. He offers the following explanation (*29*, p. 465) for this finding:

> Awareness of disturbance to language ability may create anxieties on the part of the more intelligent which less intelligent persons may not experience. The anxiety may perhaps be an important factor in the failure of the patient to make a rapid and spontaneous recovery.

The view that dysphasic symptoms are not due solely to the physical injury receives support from various investigations (*10, 11, 28*) which have reported dysphasic-like symptoms in individuals with no known brain damage. These findings are not surprising in view of the fact that some of the symptoms of dysphasia such as naming

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difficulties, paraphasic responses, and changes in tense or number, may be observed in the speech of so-called normal, or non-brain-injured, persons wl en they are fatigued or anxious.

Some writers in this area have suggested that dysphasic symptoms in an individual with brain injury may be aggravated during convalescence by the physician, hospital staff, and relatives. Aita (*1*, p. 245) found that patients reported feelings of hopelessness stemming from comments made or attitudes conveyed by doctors who cared for them. 'The physician with the vacillating, anxious, or over-cautious attitude, who warns too much against exertion, may start a disabling vicious cycle of emotional-vegetative turmoil.' In an unpublished paper Milisen[1] gives further illustration of the way in which people around the patient can foster attitudes detrimental to recovery.

A review of the literature reveals few reports of attempts to deal directly with the attitudes of those surrounding the dysphasic patient. Turnblom and Myers (*29*) concluded that a group counseling program instituted for the families of dysphasic patients helped the families make the necessary emotional adjustments to the problems of the patient and to develop objectivity in handling them. The implication is that these adjustments will be reflected in the patient's outlook and motivation and hence facilitate language recovery. However, this clinical report is based upon the authors' subjective impressions rather than upon quantified, objective data.

[1]'Aphasia: A Multi-Precipitant Disorder' by Dr. Robert Milisen, Director, Speech and Hearing Clinic, Indiana University.

The literature reveals some attempt to get at the functional component of the dysphasic patient's problem. Several writers (*2*, 7, *8*) advocate the institution of group psychotherapy with dysphasics as an adjunct to the regular speech program. Although the various writers have differed in their methods of conducting such group sessions, the central idea has been the same, namely, that of providing the dysphasic with an opportunity for airing his feelings of hostility, frustration, and inadequacy before people with similar problems, and to develop during this process some ego-strength. Aronson and others (*2*) attempted to quantify the benefits accruing from such a program. A further attempt at quantifying such findings was made by Hall (*12*), who found that counseling greatly facilitated the language flow of a dysphasic patient.

From the observations of those working directly with dysphasic individuals comes still more evidence that factors other than the injury itself are operative in determining the extent of the patient's symptomatology. To mention only a few, Zangwill (*31*), Longerich and Bordeaux (*18*), Huber (*13*), and Sheehan (*24*) advocate starting therapy as soon as the patient's condition permits in order to achieve maximal results. In one way or another, writers (*1*, *3*, *18*, *24*, *30*) concerned with the rehabilitation of dysphasic individuals stress the importance of special motivational procedures with these patients. Procedures involving failure or threat of failure are reported to result in impaired performance and, in the extreme case, in 'catastrophic reactions' with subsequent disruption of performance. On the other hand, success and re-

assurance are generally considered to be effective with such patients.

Although there has been considerable clinical comment concerning the influence of motivational factors on the recovery process in dysphasic patients, there have been few attempts to manipulate motivational variables systematically and to observe their effects on behavior. Recent studies by Blackburn (*6*) and Shankweiler (*23*) have been concerned with the effects of motivating instructions on performance on a nonverbal task (two-choice reaction time) by brain-damaged patients and by control subjects having no history of brain pathology. Contrary to clinical opinion which holds that failure results in impaired performance in the brain-damaged individual, these studies have shown that performance of both brain-damaged and non-brain-damaged individuals appears to be facilitated by experimental instructions which suggest to the subject either that he has failed or that he is likely to fail.

Other studies using normal subjects have tended to show that the effects produced by instructions are a function of the task and of the state of the individual. It would appear that nonanxious normals improve performance on an ego-involving task under threat of failure, while anxious normals perform more poorly under stress (*14, 19, 20, 22, 26*).

It is doubtful that the reaction-time task employed by Blackburn (*6*) and Shankweiler (*23*) was approached by either brain-injured or normal subjects with anxiety. Furthermore, it is unlikely that the task was considered of sufficient importance by either group to evoke emotional reactions to instructions of such magnitude as to impair performance. In the clinical situation, however, where the dysphasic subject is confronted with tasks which possess clear implications for him with respect to intellectual integrity, communicative ability, and vocational competence, it seems reasonable to expect that he would be likely to approach the situation with some anxiety, and that failure would tend to increase these feelings of anxiety or emotionality.

A survey of the literature on dysphasia points toward the view that the language performance of a dysphasic patient is influenced by the environment of attitudes created by those around him concerning his disability. One aspect of this environment, that of oral reports concerning his performance, has been chosen for study. The present investigation was designed to provide information on the effects of three kinds of motivating instructions ('encouraging,' 'discouraging,' and 'nonevaluative') on the performance of reading and naming tasks by dysphasic subjects. The questions posed were as follows: (a) Do dysphasic subjects show differences in the number of incorrect responses to language stimuli as a function of three types of motivating instructions? (b) Are these motivational effects comparable for both reading and naming tasks? (c) Do dysphasic subjects evaluate their performance as a function of the instructions which they have received?

Procedure

Subjects. The subjects were 42 diagnosed dysphasic patients, 30 males and 12 females, drawn from 11 hospitals and treatment centers located in Kansas, Iowa, Ohio, Minnesota, and New York. They ranged in age from 18 to 80 years

with a median age of 52.5 years. The 24 subjects doing the naming task had a median age of 58.0 years, and the 18 subjects performing the reading task had a median age of 44.5 years. The dysphasic condition stemmed from a cerebrovascular accident for 35 subjects, trauma for three subjects, surgical intervention for two subjects, anoxia for one subject, and a tumor for one subject. Time since onset of dysphasia ranged from one month to 10 years with a median value of 12.5 months. All subjects had an eighth-grade education or better.

Stimulus Materials. The stimulus materials for this study consisted of one set of preliminary and three sets of experimental forms (hereafter referred to as Forms I, II, and III, respectively) for each of the two language tasks. The preliminary reading form and the preliminary naming form were used for the purpose of selecting subjects for the study. Subjects who correctly produced no fewer than 20% and no more than 80% of the responses on one of the preliminary forms were included. Forms I and II constituted the stimuli used during the first two sessions with a subject when he was being conditioned to perceive the experimenter as an encouraging, or discouraging, or neutral figure. Only responses to Form III of the reading and naming tasks were used in the analysis.

The preliminary reading test and the preliminary naming test each contained 10 items, while each of Reading Forms I, II, and III and Naming Forms I, II, and III contained 30 items each. For the reading task the test items were single words typed in upper-case letters one-fourth inch high on individual 4″ x 6″ white cards; the stimuli included verbs, nouns, and adjectives. For the naming task the items consisted of pictured single objects presented as black and white line drawings on white 4″ x 6″ cards; nouns only were used for the naming task. All words used were no higher than the fifth-grade level according to graded word lists.

The preliminary form and Form III for each task were equated on the basis of seven parameters of words which have been mentioned in the literature as contributing to dysphasic speech difficulty. Siegel (*25*) has summarized these word parameters as follows: (a) recency of learning of words, (b) word difficulty, (c) grammatical part of speech, (d) phonetic composition, (e) level of abstraction, (f) length, and (g) frequency of occurrence. Criteria used by Siegel (*25*) and by Darley and others (*9*) for classifying the word in terms of these parameters were utilized. By equating the difficulty of these two forms within a task, it was hoped that all subjects included on the basis of performance within specified limits on the preliminary form would contribute information concerning the differential effect on language performance of the instructions considered in this investigation.

Responses. The subjects were required to respond aloud to each of the test items in the reading or naming task. Only the responses to Form III were tape recorded for analysis; these were replayed later and evaluated by the experimenter as being either right or wrong. If response latency was greater than 15 seconds or if the response was judged by the investigator to be significantly deviant from the acceptable utterance of the word, the response was scored incorrect.

The reliability of these judgments was checked by rescoring 11 of the speech samples a week later. A comparison of the original with the rescored ratings revealed practically no discrepancy; therefore reliability was judged sufficiently high to warrant analysis of the data.

Testing Situation. All subjects were tested individually by the same experimenter throughout. Those subjects who were able to make between two and eight correct responses on the preliminary form of either language task were assigned at random to one of the three instructions groups for that task. As previously mentioned, 24 subjects performed on the naming task and 18 on the reading task. That is, each instructions group was composed of eight subjects performing on the naming task and of six on the reading task or a total of 14 subjects. Each subject remained in the same instructions group for all three testing sessions.

Each subject was seen at three different times with sessions spaced from three to 24 hours apart. During the first session, immediately following the preliminary testing, the subject performed on Form I of the particular task under one of the three motivating-instructions conditions. The subject assigned to encouraging instructions received favorable comments preceding and during his performance. Similarly, the subject assigned to discouraging instructions received unfavorable comments preceding and during his performance. Under nonevaluative instructions, performance was preceded only by a simple explanation of the task with no comments made while the subject was responding. The same procedure was followed in all three sessions. Comments made by the investigator preceding performance on Form III are given below.

> Encouraging Instructions: 'Now we are going to do what we have done before using different (words, pictures). You pleased me last time by doing still better than you had done before. You are getting more words right each time. You are also giving me the words faster each time I see you. I'm very satisfied with what you have been able to do in the short time that I have seen you. I think that you will find the going much easier today than you have before. I expect that you will do just as well today if not better.'
>
> Discouraging Instructions: 'Now we are going to do the same thing as the other times using different (words, pictures). As I expected, you did even more poorly last time than the time before. You seem to be getting more words wrong each time. You also seem to be taking longer and longer to say the words. I am disappointed with how much you have slipped behind in the short time that I have watched you. This seems to be harder for you each time you try instead of easier.'
>
> Nonevaluative Instructions: 'I want you to do the same kinds of things as last time. We'll be working on different (words, pictures).'

While the subject responded to the stimuli, the experimenter interjected eight to 10 appropriate comments. For subjects under encouraging instructions, comments such as 'Good' and 'You're doing fine' were used. For subjects under discouraging instructions comments such as 'You missed that one' and 'That's wrong' were used.

It was felt that by the third session the subjects would have formed some opinion of the experimenter as an encouraging, discouraging, or rather neutral figure, corresponding to the instructions received. Thus, the responses during the third session only were analyzed.

TABLE 1. Mean number of errors for each instructions group on the two tasks.

Task	*Instructions Groups*		
	Encouraging	*Discouraging*	*Nonevaluative*
Naming (N = 24)	17.9	22.4	21.6
Reading (N = 18)	5.2	9.7	5.2
General Mean	12.4	16.9	14.6

At the conclusion of the third session each subject was asked to evaluate his performance. Five adjectives ,'very good,' 'good,' 'okay,' 'not so good,' and 'poor,' with scale values from one to five, respectively, were presented to him both visually and orally and he was asked to select the one which best described how he had done. This self-evaluation was included to determine whether the subject's feeling about how well he had done corresponded to the kind of instructions which he had received.

Finally, using a variety of approaches, the experimenter attempted to counteract any possible detrimental effects which discouraging and nonevaluative instructions might have had on recovery. It was felt that all subjects were reassured before they left the room.

Results

Number of Incorrect Responses. The data consisted of the responses of the 42 subjects to the 30 words or pictures on Form III of the reading or naming task. The total number of responses for all subjects was 1260 and the total number of errors was 615 or 48.9% of all the responses. The criterion measure used was the number of incorrect responses. In Table 1 are presented the mean number of incorrect responses made by the subjects in the three motivating instructions groups on the two language tasks.

A 3 x 2 factorial design (*15*) was employed for the statistical analysis with the three levels of one factor corresponding to the three kinds of motivating instructions, and the two levels of the other factor to the two language tasks. The 5% level of significance was selected. The analysis of variance results, summarized in Table 2, indicate significant differences among instructions conditions.

TABLE 2. Analysis of variance of the errors made by 42 dysphasic subjects on two language tasks under three types of motivating instructions.

Source	*df*	*ms*	*F*
Instructions (I)	2	70.93	3.71*
Tasks (T)	1	2004.02	
IT	2	16.08	
Within-Groups	36	19.68	
Total	41		

*$F_{.05}$ (df = 2 and 36) = 3.32.

The statistical tests provide for taking into account any initial differences among groups resulting from random selection of subjects. Since the subjects were assigned to the experimental conditions at random, there was no apparent biasing factor. It is of interest to note, however, that the groups were very similar initially, as indicated by pre-experimental group totals of 60, 59, and 57 errors on the 10-item preliminary task.

The difference necessary for significance at the 5% level is 3.25. Error scores under discouraging instructions are significantly greater than under encouraging instructions. The differences between encouraging and nonevaluative instructions do not reach significance at the selected level.

The subjects receiving discouraging instructions, then, experienced greater speech difficulty with both naming and reading tasks than did the subjects receiving encouraging instructions. This finding is consistent with the clinical impression that success and reassurance are essential for optimum performance of language tasks by dysphasic subjects.

TABLE 3. Means of self-evaluations on a five-point scale by subjects (in three motivating-instructions groups) of their performance on two language tasks. The lower the number, the better is the evaluation of performance.

Task	*Instructions Groups*		
	Encouraging	*Discouraging*	*Nonevaluative*
Naming	2.25	3.75	3.50
Reading	2.13	4.00	2.33
General Mean	2.21	3.86	3.00

Self-Ratings of Performance. In Table 3 the results of the subjects' self-evaluations are presented for each of the six cells. An inspection of this table reveals that subjects who were discouraged rated themselves more poorly (M = 3.86) than did the subjects who were encouraged (M = 2.21). For the subjects whose performance was not evaluated, the general mean for both tasks fell midway between the other two means (M = 3.00). For the individual tasks the results follow the same pattern except that for the naming task the mean of the nonevaluated group is closer to that of the discouraged group while for the reading task it is closer to that of the encouraged group. Due to the large number of ties in individual scores a nonparametric statistical test was contraindicated. It is apparent, however, that the subjects evaluated their performances according to the instructions which they received. A comparison of the information in Table 1 with that in Table 3 also reveals a close correspondence between the means of the subjects' self-ratings and the results obtained in terms of number of incorrect responses.

Discussion

Instructions Conditions. It is obvious that the results of this study are largely dependent on how convincing the experimenter was in conveying certain attitudes through the use of motivating instructions. Admittedly the situations created were artificial. They involved many uncontrolled variables which enter into producing the desired environment, such as the interaction of the experimenter's and the subject's personalities and the ability of the experimenter to act out the instructions regardless of the individuals involved.

Instructions effects were controlled to some extent by using standard instructions for all within a given instructions group, by having the same experimenter provide all three instructions, by attempting to act out the instructions rather than read them, and by taking care to ensure that all comments made during the course of a session were consistent with the tone of the instructions.

Some evidence to support the view that these three sets of instructions actually differed is provided by the subjects' self-ratings, which are consistent in direction with the instructions received by the subjects. Moreover, subjects' reactions during the testing situation tended to confirm that these instructions were in fact what they purported to be. Under discouraging instructions two subjects approached catastrophic behavior. Although the other individuals subjected to discouraging instructions did not display such extreme responses, they reflected the instructions in their appearance; as a group they tended to be withdrawn, tense, and unsmiling during their sessions. The subjects receiving encouraging instructions were, on the whole, spontaneous, f r i e n d l y, and smiling throughout the experiment. In the nonevaluated group, no such uniformity of response was observed. It is likely that more than one interpretation was placed on the experimenter's nonevaluative instructions by the subjects who received them.

Language Tasks. It is interesting to note that the subjects in the naming group were more deficient in the language area than were those in the reading group. The subjects in the reading group were able to do the naming task perfectly or almost perfectly, whereas in no instance was an individual in the naming group able to respond correctly to even two of the reading task items.

Except in the matter of age, the subjects in the two language groups were alike in most respects, such as time since onset of the dysphasic condition and amount of therapy received. Unless this is a chance happening, the fact that the subjects in the naming group were older than those in the reading group would tend to lend support to the view that the younger the dysphasic subject, the better his language recovery.

Number of Incorrect Responses. The findings in the present study do not accord with those of Blackburn (*6*) and Shankweiler (*23*), who demonstrated facilitation of nonverbal performance for brain-damaged patients under failure instructions. Assuming that the dysphasic is anxious about his language performance, the findings of this study accord with what other studies have found concerning the effects of increased anxiety on so-called normal individuals. Increasing the already existing anxiety by discouraging instructions has the effect of lowering the efficiency of the dysphasic's performance. Decreasing the anxiety by encouraging instructions has the effect of raising the level of performance over that of discouraging instructions.

Level of Difficulty of Tasks. Because of subject sampling or item sampling or a combination of both, the objective difficulty of the reading task is obviously less than that of the naming task. The susceptibility of the dysphasic patient to the attitudes of those around him is demonstrated by the comparable effects of encouraging and discouraging instructions in the two tasks in spite of the level of difficulty of the test items in these tasks. That is to say, even when the dysphasic patient is functioning at a very low level and is meeting almost continual failure in responding to the stimuli presented to him (as in the naming task), his performance and his opinion of it can be manipulated by verbal

suggestion. Similarly, at a high level of performance when the dysphasic individual is meeting with almost continual item success (as in the reading task), his performance and his self-evaluation can be manipulated in the same manner.

The finding that the results of discouraging and encouraging instructions obtained when the objective success varied would again seem to confirm the position that the dysphasic subject approaches verbal performance with anxiety and that he is more apt to believe what others tell him than to rely on his own judgment.

Self-Ratings. The use of a scale for self-evaluation of speech performance was included to determine the effects of instructions on self-concepts. It is interesting to note how the obtained means accorded with the experimental instructions and results. When it is considered how many factors enter into self-evaluation, the differences between instructions groups found here are an indication of how susceptible brain-damaged individuals are to the environment of attitudes created by those around them.

Clinical Implications. The significance of the instructions effects on speech performance in spite of the many variables in the experimental conditions which could not be controlled (such as time of day and acting ability of the experimenter from one day to the next) would seem to demonstrate the importance to the subject's language recovery of the evaluations made by people around him. The instructions effects would seem to indicate that it is not sufficient to work only with the dysphasic patient but that the clinician's responsibility extends to making those around the dysphasic patient aware of his problems. A counseling program for relatives and friends of the patient would seem to be desirable for maximum recovery of language facility.

The fact that such results as those noted in this study can be produced in subjects whose dysphasia has been of some months' duration (median of 12.5 months) argues for very careful handling of the patient by those who come into contact with him directly after onset of dysphasia. The patients used in this study had had time to adjust to the fact that they were no longer able to communicate as well as before in a society where a premium is placed on language ability. It would seem that the effects which might be produced immediately after onset by such instructions conditions would be even more pronounced. The experimental findings suggest the extreme importance of the early experiences of the dysphasic patient on the course of his language recovery.

Inasmuch as the results of this experiment were produced by comparatively short exposure to instructions conditions, it is not unreasonable to conclude that there is a psychological component in the dysphasic's problem at least for some patients and probably for all of them in some situations. The facilitating and inhibiting influences of instructions effects have been explained in terms of anxiety. The implications for the clinician include taking such positive steps to reduce this anxiety as early institution of therapy and the keeping of detailed records for demonstrating language gains to the patient.

The nonevaluative instructions used

in this investigation provide some further clinical insights. These instructions closely parallel the typical psychological test situation in which subjects are instructed to do their best at the beginning but are subsequently given no knowledge of results and no further encouragement (or, at most, minimal encouragement) during the course of testing. In diagnostic testing of dysphasic subjects where the clinician is interested in determining the individual's maximum performance, the evaluations stemming from such a nonevaluative situation may be misleading.

Summary

The speech behavior of 42 dysphasic subjects following three types of motivating instructions ('encouraging,' 'discouraging,' and 'nonevaluative') was investigated in terms of number of errors on naming and reading tasks and self-ratings of performance. The obtained results indicate that dysphasic patients subjected to discouraging instructions do significantly more poorly on language tasks than do those under encouraging instructions. Moreover, dysphasic patients under discouraging instructions rate their performances more poorly than do those under encouraging instructions. These findings were interpreted as demonstrating a psychological component in the symptomatology presented by the dysphasic individual. The concept of anxiety, suggested by other writers, was postulated to account for the obtained results. The implications of these findings for clinicians and for others associated with the dysphasic individual were discussed in terms of the need for expressing positive attitudes and actions concerning language recovery.

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Text. Begin text on page two. At top of page, flush left, type title, capitalizing important words; below title, flush left, type author name or names, one name to a line, with normal capitalization. Below author name(s) begin text, the first line flush left. After this use normal paragraph indention on all paragraphs of text and footnotes.

Key items from the reference list to the text by placing the appropriate reference number (see below under *References*), underlined and in parentheses, after the name of the author(s); or if an author name is not used at that point, directly after the subject to which the reference relates, always using it as early as possible in the sentence. Within the parentheses, with the reference number, include page numbers or chapter for books but do not include page numbers for articles. When mentioning an author or authors in the text, use only the surname; when more than three authors are involved in a particular study being referred to, use the surname of only the senior author with the words 'and others.' Thus text might read 'Jones, White, and Smith (*11*, pp. 45-67) have supported this position while Brown and others (*9*, chap. 5) present evidence indicating that studies by Wilson (*14*, *16*) are . . . .' Here the first two studies would be found in books, the Wilson studies in journals; for the study by Brown and others there were more than three authors.

Use headings within text to indicate levels of subordination: first level, flush

left, underlined, on a line by itself, important words capitalized, without period; second level, normal indention, underlined, important words capitalized, with period, and with text sentence beginning on same line; third level, same as second level except not underlined. ('Preparation of Manuscript,' 'Order of Pages,' and 'Page One,' above, are examples of first-, second-, and third-level headings, respectively.) Write copy following each heading so that it is complete without the heading; that is, do not begin the sentence following the heading with a pronoun which refers to the heading or with a statement which infers presence of the heading.

When it is necessary to use footnotes, label them in consecutive order with numerical superscripts and refer to them in text with corresponding numerical superscripts. The superscript in the text may be used with a word within a sentence or may come at the end of a sentence. At the end of a sentence always place the superscript after the period; when the within-sentence word happens to be followed by punctuation, then place the superscript after that punctuation.

Introduce each footnote, double spaced and with normal paragraph indention, into the text directly on mention, setting it off from the text by solid lines above and below. Include in footnotes, in addition to the usual kind of explanatory material, any reference to material which is unpublished and therefore not available to the reader: this includes personal correspondence and items not listed by a library or by the American Documentation Institute (ADI) of the Library of Congress. However, place in the reference list and not in footnotes unpublished materials which are available in a secondary source; place in the reference list all theses, whether published or unpublished.

Summary. At the end of the article, present a *Summary* section of not more than 150 words (at this length the *Summary* is often used as an abstract by other journals). Present *Summary* as a first-level heading.

Acknowledgment. Limit any statement of acknowledgment of help to a few individuals. Place such a paragraph, if one is included, at the end of the article but before the reference list, giving it a first-level heading, *Acknowledgment.*

References. For the style of the reference listing see a recent issue of the *Journal.* Begin the reference listing on a separate sheet of paper regardless of where the text copy ended on the preceding page. At the top of the page indicate *References* as a first-level heading. Under the heading type the list of reference items, double spaced and flush left, numbered in the alphabetical order of senior author surnames. Use the names of all authors in this listing. Invert all author names, using initials for the men, spelled-out first names with or without initials for the women, thus: Jones, J. H., Smith, Martha, Brown, M. L., Hunt, Jane E., and Wilson, R. M. (Note that only in the text is there use of the 'and others' form.) Give inclusive page numbers for all articles in periodicals (but page or chapter numbers of books in the text and not in the reference list). For government documents include PB num-

bers whenever they are available. For publications listed by the Armed Services Technical Information Agency include ASTIA numbers. List unpublished material available from a secondary source with the notation 'cited in. . . .' For additional information concerning reference to unpublished materials see *Footnotes* above.

To abbreviate titles of publications, follow the style of the *World List of Scientific Periodicals* or use the abbreviations in reference lists in recent issues of the *Journal of Speech and Hearing Research*. When in doubt, include the complete title (in marking copy for the printer it is easier to indicate the correct abbreviation from the complete title than it is from an incorrect abbreviation).

Tables. Refer to all tables in text but design each table so that it is complete in itself. Develop a concise headnote; keep column headings brief but succinct; include in the tabulation only that information which the reader needs. Do not include dependent items (for example, in an analysis of variance summary the sums of the squares are not necessary when mean squares and degrees of freedom are given). Arrange the table with the printed page in mind: if there are three headings one way and 10 the other, place the three across the table and the 10 up and down. Excellent help in developing a table may be found in the *Publication Manual* of the American Psychological Association.

Type each table, double spaced, on a separate sheet of paper. Number the tables consecutively with Arabic numerals but number the pages in the appropriate sequence for the entire manuscript, with Table 1 following the reference list. Begin each headnote flush left with the word 'Table,' the appropriate number, and a period, followed on the same line by the headnote copy, thus: Table 1. Analysis of variance. . . . Continue in the flush left style for the entire headnote. Below the headnote place double horizontal rules; then column headings, underlined, important words capitalized; then a single rule under the headings; then the body of the table; then double horizontal rules (bottom of the table). Below the double rules place the footnotes, if any. Do not use horizontal rules, short or long, within the table. If there are cells in the table for which there are no entries, leave these spaces blank; do not fill in with dashes or other marks.

Type table footnotes double spaced and flush left. Label them in this sequence: asterisk, dagger, double asterisk, double dagger, ... Do not be concerned when, by virtue of this sequence, a symbol refers to one thing in one table and to something else in another; the symbols have no intrinsic meaning but are simply a reference device (for example, an asterisk in Table 1 may refer to significance at the 5% level, an asterisk in Table 2 may refer to significance at the 1% level, an asterisk in Table 3 may refer to a mean threshold value). If mathematical expressions or formulae are used in table footnotes, render them in one line when possible to avoid use of built-up fractions; always use a fractional exponent rather than a radical sign. Keep use of footnotes to a minimum.

Figures. Refer to all figures in text but design each figure to be complete

in itself. Place each figure on a page by itself, without a legend; place the legends for all figures together on a single page (or pages if more than one page are needed). Place the legend page(s) after the last table; then the figure pages in numerical order. When possible submit copies (preferably glossy prints) rather than the originals of figures as a protection against the damage or loss which might occur in mailing.

On the figure legend page(s) type the legends double spaced and flush left, arranging them one after another in numerical order. Begin each legend with the word 'Figure,' the appropriate number, and a period, followed by the legend copy on the same line, thus: Figure 1. Diagram of . . . . As in the table headnote, continue the flush left style throughout the legend.

Furnish clear copy for all figures. Draw figures boldly, being mindful of the relation of the size of lettering to the area in order that the lettering will be readable when it is reduced for printing. Use black ink and white paper (blue tracing linen or white graph paper with blue lines is acceptable because the blue photographs white). Identify each figure on its reverse side giving author name, article title, figure number; indicate, also on the back, which is the bottom of the figure. Write with light pressure in order not to mark through to the front of the figure.

Miscellaneous Specifics

When there is the possibility of inappropriate interpretation, avoid using these and related terms: speech therapist, speech therapy, defective individual, cleft palate child, patient. Use instead such terms as speech correctionist, or clinician, or speech pathologist, or audiologist; speech and hearing services, or speech correction, or counseling; individual with articulation disorder or with faulty speech or with hearing loss; children with cleft palates; case, or pupil, or student, or child, or person.

Copy all reference titles exactly as they appear in print, even if this makes the present reference list inconsistent within itself and with *Journal* style. Thus, if 'lipreading' is used as a single word in one title, two separate words in the next, and some other way in another, render it in those various ways in the listing. Fidelity to the original is of great importance because the basic reason for listing references at all is to give absolutely accurate information for use of the interested reader who wishes to find them.

Use the following forms for these words or expressions: wavelength, wave form, x ray (noun), x-ray (adjective), per cent, nonfluency, lipreading, so-called, over-all, feedback, sidetone, band width, 0.0002/dyne/cm^2 (not dynes).

Avoid italics or underlining for emphasis.

Use italics for titles of books, to refer to sections of the manuscript (as, in the *Discussion* section), and in similar limited ways.

Italicize *t* (as in *t* test), *df*, *F*, *q*, *z*, *r*, *P*, *SD*, and similar statistical expressions.

Within running text do not italicize re, N (when meaning number), versus, phi, chi, and foreign words which have become part of the English language.

To pluralize statistical expressions, add 's' without an apostrophe; thus, *SD*s, *r*s. Note that most such expressions do not include periods. When ex-

pressions of this type are commonly used both with and without periods (I.Q., IQ) choose the style without periods.

Use hyphens in adjective phrases of two or more words preceding and modifying nouns when meaning is unclear without hyphenating them: equal-appearing intervals, speech-handicapped individual, two-minute samples, but pure tone audiometry. When in doubt do not hyphenate.

Never hyphenate a word and its prefix or suffix unless this is indicated in Webster's unabridged dictionary; most words of this type are not hyphenated.

Do not hyphenate such expressions as *t* test, *F* test, chi square when they are used as nouns. Hyphenate them only when they are used adjectively, thus: *t* test, *t*-test results.

Use small letters in preference to capitals whenever feasible.

Use comma after 'and' in series of three or more.

Do not use comma in numbers.

In general do not punctuate within a table; information which might be carried by punctuation should be clear from the arrangement and labeling of items.

Enclose phonetic symbols in square brackets, phonemic symbols in diagonal lines.

Enclose primary quotations in single quotation marks; quotations within quotations in double quotation marks (this so-called English style is of course the reverse of the more common American style). Always place quotation mark outside period or comma.

Consult a good style book on whether the quotation mark goes inside or outside other punctuation (here the position depends on meaning).

Insofar as feasible, avoid the use of quotation marks for purposes other than that of setting off direct quotations.

Avoid abbreviations such as i.e., viz., e.g., in running text; use their translations instead.

Abbreviate expressions of measure when they refer to a definite amount except when they are isolated in descriptive matter and are a part of running text, thus: 6 cps, 70 db, but he read for six minutes. Do not use periods with abbreviations except with in., the abbreviation for inches (to avoid confusion of the abbreviation and the word 'in').

Use the % sign with numbers.

Use the inch sign in this type of expression: 2″ x 5″ card.

Always use Arabic numerals with abbreviations of measure.

Use Arabic numerals for numbers of two or more digits. In running text write out one-digit numbers except when they are used with abbreviations of measurement (see above) and except in a series where they appear with numbers of more than one digit. In both of these cases use numerals for all.

Do not begin a sentence with a number of two or more digits.

Change fractions to decimals when that is feasible; use decimals of not more than two places unless more are demanded for accuracy or usefulness in reporting. For example, it would seldom be meaningful to report a correlation coefficient beyond two places.

Render formulae in a single line if possible, for example,

$$F = \mathrm{ms}_A/\mathrm{ms}_{AS}, \text{ not } F = \frac{\mathrm{ms}_A}{\mathrm{ms}_{AS}}$$

Do not number items in a list but refer to them by a, b, c, . . . to avoid confusion with the reference numbers.

Examples of Manuscript Form

Author Identification Paragraph

John Doe (Ph.D., University of Iowa, 1957) is Professor of Speech Pathology, University of Iowa. This article is based on a Ph.D. dissertation completed under the direction of Dr. James Smith and is adapted from a paper given at the 1957 convention of the American Speech and Hearing Association, Cincinnati. The research was supported by a grant from the Speech Correction Foundation.

Title and Author Name(s)

Pitch Level and Harshness

John Brown

Mary White

First-Level Heading

Results

Analysis of the pooled data by t tests for related means established that a significantly larger number of phonatory blockages ($t = 8.89$; $df = 7$; $t_{.01} = 3.49$) and

Second-Level Heading

Subjects. Subjects were 14 males and 15 females who ranged in age from 23 to 51 years with a mean age of 30 years. All had normal hearing and all were

Third-Level Heading

Comparisons among Subjects. The relationship between the number of subjects correctly articulating /r/ within a given phonetic context and the percentage of

Reference Numbers in Text

Rahn and others (23) and Lillehei and Balke (22) each found, independently, that performance was little affected until carbon dioxide tension fell below 25 mm Hg. Clinical reports (6, p. 68, 9) have indicated that hyperventilation often

Footnote

The conditioned stimulus was presented at hearing levels of 5 db, 10 db, and 20 db above the rounded SRT W-1.[1] When the conditioning schedule called for a

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[1] A variable-intensity conditioned stimulus was selected on an arbitrary basis, but a fixed level might have served equally well.

---

reinforced presentation of the conditioned stimulus, the interval between the onset of the conditioned stimulus and the onset of the unconditioned stimulus was

Reference Page

References

1. Békésy, G.v., The mechanical properties of the ear. In S.S. Stevens (Ed.), Handbook of Experimental Psychology. New York: John Wiley, 1951.

2. Black, J.W., Natural frequency, duration, and intensity of reading. J. Speech Hearing Dis., 14, 1949, 216-221.

3. Brackett, I.P., A study of the growth of inflammation on the vocal folds accompanying easy and harsh production of the voice. M.A. thesis, Northwestern Univ., 1937.

4. Fairbanks, G., Voice and Articulation Drillbook. New York: Harper, 1940.

5. Taylor, Janet, A personality scale of manifest anxiety. J. abnorm. soc. Psychol., 48, 1953, 285-290.

Tables

Table 1. Distribution of frequencies of choices of story content by 36 second-grade children and results of the chi-square test.

Stories	Choices			Chi Square*
	1st	2nd	3rd	
1	8	16	12	2.67
2	14	8	14	2.00
3	14	11	10	.75

*A chi-square value of 5.99 (df = 2) is required for significance at the 5% level.

Table 5. Mean values of initial habit strength and resistance to extinction relevant to the intensities of the conditioned tone and the extinction tone (shock levels pooled).

Extinction Tone	Conditioned Tone			
	30 db	60 db	90 db	Mean
Initial Habit Strength				
30 db	1.89	1.53	1.90	1.77
60 db	4.05	3.43	1.88	3.09
90 db	7.69	4.83	2.07	4.67
Mean	4.35	3.19	1.95	
Resistance to Extinction				
30 db	1.34	0.70	0.69	0.91
60 db	1.32	2.28	1.27	1.61
90 db	2.86	2.20	1.98	2.33
Mean	1.81	1.71	1.30	

Table 2. Pearson product-moment correlation coefficients for all possible pairs of language measures. (With 54 df, a correlation of .26 is significant at the 1% level, .34 at the 5% level.)

Language Measures	2	3	4	5	6	7	8
1 Length of Written Composition	.57	.63	.27	.51	.24	.44	.49
2 Development of Written Sentence		.69	.59	.70	.48	.59	.71
3 Length of Written Sentence			.58	.59	.56	.47	.56
4 Length of Spoken Composition				.65	.88	.42	.52
5 Development of Spoken Sentence					.45	.43	.56
6 Length of Spoken Sentence						.40	.51
7 Lipreading							.61
8 Reading Grade Level							

Table 2. Summary of analysis of variance for evaluation of mean severity ratings of vowels and voiced consonant environments.

Source	df	ms	F^*	$F^+_{.05}$
Vowels (V)	8	2.93	7.71	2.05
Consonants (C)	3	3.91	11.85	2.90
Speakers (S)	11	33.08		
VC	24	.37	1.00	1.57
VS	88	.38		
CS	33	.33		
VCS	264	.37		
Total	431			

*F ratios: ms_V/ms_{VS}; ms_C/ms_{CS}; ms_{VC}/ms_{VCS}.

+$F_{.05}$ is the tabled value for the nearest given df.

Table 1. Comparisons of the scale values of 24 nasal voices for Passage 1 and Passage 2 from the same paragraph, obtained by Method A, from judgments on samples played forwards, and by Method B, from judgments on samples played backwards.

	Mean	Diff.	$SE_{diff.}$	t^*	r
1-A	3.69	.15	.13	1.154	.89
2-A	3.84				
1-B	3.58	.14	.16	.875	.89
2-B	3.72				

*$t_{.05}(df = 23) = 2.069$.

Table 2. Summary of median error scores and ranges of individual error scores for each of three groups at six sensation levels of delayed speech feedback.

Group		Sensation Level in db					
		0	10	20	30	40	50
Normal	Median	4.5	5.0	6.5	9.0	10.5	17.0
	Range	16	19	21	26	23	23
Hydrops	Median	12.0	14.5	17.0	22.0	28.0	24.0
	Range	26	28	32	35	34	24
Masked Normal	Median	5.0	9.0	14.0	17.0	21.0	25.0
	Range	15	33	36	32	28	31

Table 1. Means and standard deviations in decibels for speech detection threshold (SDT), speech reception threshold (SRT W-1), threshold of perceptibility for running speech (TPRS), and conditioned GSR auditory speech threshold (GSR); N=30.

Measure	Mean*	Standard Deviation
SDT	16.47	3.45
SRT W-1	25.47	3.85
TPRS	28.93	3.00
GSR	22.83	3.80

*Mean threshold values re 0.0002 dyne/cm^2.

Table 1. Mean threshold losses in db sensation levels for first-, third-, and fifth-grade ears and for all ears combined.

Grade	N	Frequencies (cps)				
		500	1000	2000	4000	8000
1	31	16.29	16.77	14.35	21.77	15.97
3	34	22.06	22.21	20.59	31.18	17.79
5	25	15.40	14.00	14.00	23.60	11.20
All	90	18.22	18.06	16.61	25.83	15.33

Figure Legends

Figure 1. Variation of relative message effectiveness with relative message time. Upper scale: rate in words per minute.

Figure 2. Variation of rate learned with rate presented: A, experimental; B, items correct unchanged by reduction of message time; C, items correct proportional to message time.

Figure 3. Cumulative number of items correct during message at various experimental conditions, rates labeled in words per minute. Broken line is reference curve for test-only condition.

Figure 4. Mean response score (obtained percentage correct minus test-only percentage) for the various experimental conditions.